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User's Manual for DuctE3D: A Program for 3D Euler Unsteady Aerodynamic and Aeroelastic Analysis of Ducted Fans

R. Srivastava and T.S.R. Reddy
University of Toledo
Toledo, Ohio

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User's Manual for DuctE3D: A Program for 3D Euler Unsteady Aerodynamic and Aeroelastic Analysis of Ducted Fans

Version 1.0

R. Srivastava*
T. S. R. Reddy*

Department of Mechanical Engineering
University of Toledo
Toledo, Ohio 43606

SUMMARY

The program DuctE3d is used for steady or unsteady aerodynamic and aeroelastic analysis of ducted fans. This guide describes the input data required and the output files generated, in using DuctE3D. The analysis solves three dimensional unsteady, compressible Euler equations to obtain the aerodynamic forces. A normal mode structural analysis is used to obtain the aeroelastic equations, which are solved using either the time domain or the frequency domain solution method. Sample input and output files are included in this guide for steady aerodynamic analysis and aeroelastic analysis of an isolated fan row.

*NASA Resident Research Associate at Lewis Research Center

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1. INTRODUCTION

This is a user's guide for the DuctE3D (Ducted Fan Euler Three Dimensional Analysis) computer code, which has been developed for steady or unsteady aerodynamic analysis and flutter analysis of fan configurations. This guide will help the user in the preparation of the input data file required by the DuctE3D code. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this guide. Instead, the reader is directed to specific references that deal with each of these items. The DuctE3D code was developed under the direction of the Structural Dynamics Branch at NASA Lewis Research Center. It is made available strictly as a research tool. Neither NASA Lewis Research Center, nor any individuals who have contributed to the development of the code, assume any liability resulting from the use of this code beyond research needs.

2. ANALYSIS

The aerodynamic analysis used in this code is based on the unsteady three-dimensional Euler equations. These eqnations are solved for a fan configuration. The coordinate system used is shown in Fig. 1. Detailed descriptions of the aerodynamic analysis can be found in Refs. 1 and 2. These references contain a full description of the formulation including the governing equations and the boundary conditions. The transformation of the equations to the computational plane and the subsequent discretization and solution of these equations is also described. A finite difference Alternating Direction Implicit (ADI) scheme is used to solve the Euler equations. A hybrid implicit-explicit scheme is used to reduce computational time. The aeroelastic analysis is described in Refs. 3 and 4. The aeroelastic equations are formulated in normal mode form and are solved for flutter in both time and frequency domains. For the time domain analysis, the aeroelastic equations are integrated in time using Newmark's method. The nature of the response indicates the stability. For the frequency domain aeroelastic analysis, the blades are moved in a prescribed pulse motion. The time history of the forces (generalized forces), due to the pulse motion, is Fourier analyzed to obtain unsteady aerodynamic coefficients. These unsteady aerodynamic coefficients must then be used in a separate eigen analysis to determine the stability of the fan. This eigen analysis is carried out as a post processor and is not described in this manual

3. DESCRIPTION OF INPUT DATA

The DuctE3D code is written in FORTRAN. It was developed and is operational on the Cray YMP computer at NASA Lewis Research Center under the UNICOS operating system. The source code is designated as *ducte3d.f*, and the input data for the code is provided in the input file *ducte3d.inp*.

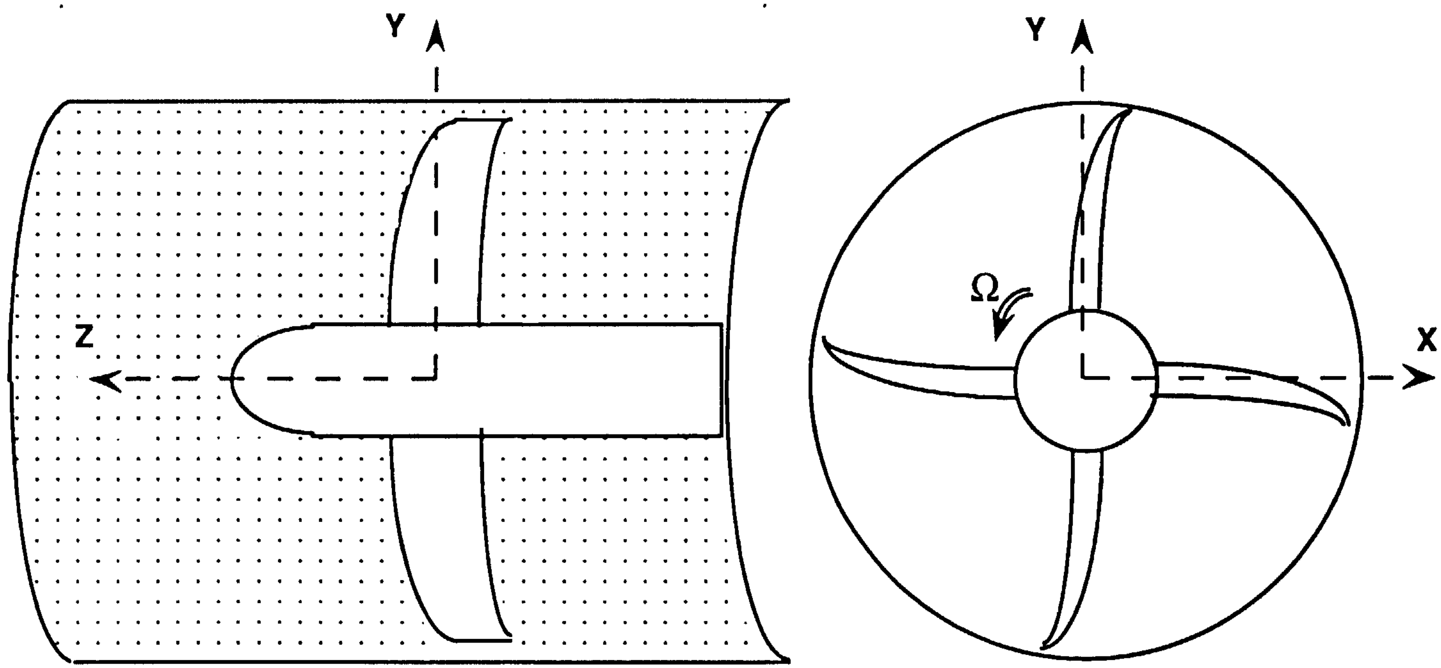

Figure 1. Axis system used by DuctE3D

3.1 Dimension Statements

The source code contains a parameter card that defines the largest possible size of the grid and number of blocks (passages) for calculation. For a larger grid size, the parameter statement should be changed **globally** in the source code. An example card is as follows:

```
parameter(imx=100,jmx=33,kmx=33,nblk=8,kmd=3,nblk3=nblk*3+1)
```

where

imx = maximum number of grid points in the axial (chordwise) direction

jmx = maximum number of grid points in the radial direction

kmx = maximum number of grid points + 1 in the circumferential direction

nblk = maximum number blade passages for computation

kmd = maximum number of structural modes in the analysis

3.2 Input Data File: ducte3d.inp

This file contains the standard (UNIT 5) input that the DuctE3D code requires. In the input file, the values of each set of input variables is preceded by an informational line containing the names of the variables. The name of the variables listed on the informational line are not used by the program. Following this line the values of the variables are listed. The real values are read in 8F10.4 format and integer values are read in 8I10 format. There are also a few logical variables that require either 'true' or 'false' as inputs.

The input variables are described below in the order in which they are required in the input data file (sample input file is shown on page 16). The informational card is listed first, followed by the description of the variables appearing on this informational card. Sample values are also given.

The first card is a title and can be up to 80 characters long.

example: SR3CX2 DUCTED PROPFAN AEROELASTIC ANALYSIS

```
ADV       GMU       ALFA      PSI       WW        DT      REYREF
```

variable: ADV
type: real variable
description: advance ratio
example: 3.55

variable: `GMU`
type: real variable
description: not used
example: `0.0`

variable: `ALFA`
type: real variable
description: angle of attack of center body with respect to free stream
example: `0.0`

variable: `PSI`
type: real variable
description: not used
example: `0.0`

variable: `WW`
type: real variable
description: artificial dissipation factor
example: `7.0`

variable: `DT`
type: real variable
description: time step, suggested values 0.0001 <DT<0.005
example: `0.003`

variable: `REYFRE`
type: real variable
description: only Euler analysis permissible, must specify a negative number
example: `-1.0`

```
IMAX   JMAX   KMAX   JTIP   ITEL   ILE   INOSE
```

variable: `IMAX`
type: integer variable
description: total number of grid points in axial direction (≤ imx)
example: `100`

variable: `JMAX`
type: integer variable
description: total number of grid points in radial direction, hub to tip and beyond (≤ jmx)
example: `33`

variable: `KMAX`
type: integer variable
description: total number of grid points in circumferential direction + 1 (≤ kmx)
example: `22`

variable: `JTIP`
type: integer variable
description: number of grids up to the tip of the blade along radial direction
example: `20`

variable: ITEL
type: integer variable
description: number of grid points between downstream boundary and trailing edge
example: 30

variable: ILE
type: integer variable
description: number of grid points between upstream boundary and leading edge
example: 36 .

variable: INOSE
type: integer variable
description: number of grid points between the nose of the hub and upstream boundary
example: 16

```
FSTP     FMINF    BETA34     DIA      DX      DZ    VIBFRE
```

variable: FSTP
type: real variable
description: total number of time steps
example: 1800.0

variable: FMINF
type: real variable
description: free stream Mach number
example: 0.50

variable: BETA34
type: real variable
description: blade setting angle at 75% radius from plane of rotation in degrees (used only if grid is internally generated)
example: 61.2

variable: DIA
type: real variable
description: diameter of the propeller
example: 1.0

variable: DX
type: real variable
description: the distance of the first grid point off the blade in the axial direction, as a percentage of local chord (used only if grid is internally generated)
example: 0.01

variable: DZ
type: real variable
description: the distance of the first point off the blade in the direction normal to the blade, as a percentage of local chord. Used only if grid is internally generated.
example: 0.02

variable: VIBFRE
type: real variable
description: vibration frequency in Hz or pulse width in nondimensional time used in frequency domain flutter analysis
example: 0.6

ICCW ITURB LTHIN IGR ISWF

variable: ICCW
type: integer variable
description: indicator for direction of rotation of the propeller, see Fig. 1
example: 0 rotates clockwise (-ve Z rotation)
1 rotates counter-clockwise (+ve Z rotation)

variable: IFAN
type: integer variable
description: must be set to 1 for ducted
example: 1

variable: ITURB
type: integer variable
description: viscous runs (not used)
example: 1

variable: LTHIN
type: integer variable
description: viscous control (not used)
example: 0

variable: IGR
type: integer variable
description: control for reading in the computational grid, see subroutine WINGEO for detail
example: 0 algebraic aerodynamic grid generated within the program
1 externally generated aerodynamic grid is read in from UNIT 2, input file

variable: ISWF
type: integer variable
description: control for output of computational grid
example: 0 no print out
1 print grid (aerodynamic mesh) to UNIT 7 output file

P0 T0 A0 PRATIO

variable: P0
type: real variable
description: static pressure (psi)
example: 14.7

variable: T0
type: real variable
description: total temperature of the freestream in Rankine
example: 528.0

variable: `A0`
type: real variable
description: sonic velocity of the fluid (inch/sec)
example: `13040.0`

variable: `PRATIO`
type: real variable
description: static pressure pressure ratio
example: `1.0`

RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD and DUCT

variable: `RESTART`
type: logical variable
description: restart option
example: `FALSE`: start new case
`TRUE`: restarts, will read grid and flowfield information from UNIT 11 input file

variable: `QUASISTEADY`
type: logical variable
description: quasisteady or unsteady
example: `FALSE`: unsteady case
`TRUE`: quasi-steady case

variable: `INFLOW`
type: logical variable
description: must be set to `FALSE`
example: `FALSE`

variable: `AEROELASTIC`
type: logical variable
description: aerodynamic or aeroelastic analysis
example: `TRUE`: aeroelastic analysis
`FALSE`: aerodynamic analysis

variable: `COUNTER ROTATION`
type: logical variable
description: single or counter rotation analysis
example: `FALSE`: single rotation analysis
`TRUE`: counter rotation analysis

variable: `RESABD`
type: logical variable
description: restart for deflection calculations
example: `FALSE`: restart values are used
`TRUE`: will read previous solution but generates grid

variable: `DUCT`
type: logical variable
description: ducted or unducted analysis
example: `FALSE`: unducted geometry
`TRUE`: ducted geometry

IFLTR NUMCYC NSTDY JMODE NBLOKS

variable: IFLTR
type: integer variable
description: flutter analysis control, ignored if aeroelastic is FALSE
example: < 0 time domain flutter analysis
> 0 frequency domain flutter analysis

variable: NUMCYC
type: integer variable
description: number of cycles of harmonic oscillations, ignored for other cases
example: 3

variable: NSTDY
type: integer variable
description: type of oscillation used for frequency domain flutter analysis, ignored for other cases
example: 1 harmonic oscillations
2 pulse oscillation, VIBFRE is treated as pulse width

variable: JMODE
type: integer variable
description: mode number in which the blade is to be oscillated for frequency domain flutter analysis, ignored for other cases
example: 2

variable: NBLOKS
type: integer variable
description: number of blade passages used in the analysis, number of blades should be an integer multiple of NBLOKS
example: 1

NOTE : The following data line is required only for counter-rotation analysis. It must be removed for any single-rotation analysis.

XLOC DIAA BETAA ITELA ILEA

variable: XLOC
type: real variable
description: axial distance of the pitch change axis of aft fan from the pitch change axis of front fan
example: 23.776

variable: DIAA
type: real variable
description: diameter of the aft fan
example: 140.0

variable: `BETAA`
type: real variable
description: setting angle of the aft fan
example: `54.4`

variable: `ITELA`
type: integer variable
description: number of grid points from trailing edge of aft fan to downstream boundary.
example: `38`

variable: `ILEA`
type: integer variable
description: number of grid points upstream of leading edge of aft fan
example: `8`

FNRS

variable: `FNRS`
type: real variable
description: number of axial data points to define center body or hub, converted to integer inside the program
example: `63.010`

NOTE: a total of FNRS values of XR and RR should follow

XR RR

variable: `XR`
type: real variable
description: value of the axial station defining hub geometry
example:
```
0.1
0.2
...
...
1.5
```

variable: `RR`
type: real variable
description: value of hub radius at axial station XR
example:
```
0.05
0.08
...
...
0.225
```

XLED ZLED CHORD

variable: XLED
type: real variable
description: axial distance of the leading edge of the duct from the pitch change axis
example: -5.0

variable: ZLED
type: real variable
description: radial distance of the leading edge of the duct from the axis of rotaion
example: 0.505

variable: CHORD
type: real variable
description: chord length of the duct, normalized with the diameter
example: 2.0

FSYM FNU FNL

variable: FSYM
type: real variable
description: symmetry parameter
example: 0 non-symmetric airfoil cross-section
1 symmetric airfoil cross-section

variable: FNU
type: real variable
description: number of points on the upper surface of airfoil, converted to integer within the program
example: 33.0

variable: FNL
type: real variable
description: number of points on the lower surface of airfoil, converted to integer within the program, must be same as FNU
example: 33.0

NOTE: a total of FNU values of X and Y should follow

X Y

variable: X
type: real variable
description: value of the axial station defining duct geometry
example: 0.000
0.025
...
...
0.225

variable: Y
type: real variable
description: value of duct radius at axial station XR
example:
```
0.000000
0.005765
...
...
0.022514
```

INASTRAN

variable: INASTRAN
type: integer variable
description: static aeroelastic analysis, ignored if `aeroelastic` is `false`
example:
`1` static aeroelastic analysis
`0` no static aeroelastic analysis

FNC FROTAT FB FTPRP FTWST FCOB FGR

variable: FNC
type: real variable
description: number of stations at which blade is defined, converted to integer within the program
example: `13.0`

variable: FROTAT
type: real variable
description: for future use, must use a value of 1.01
example: `1.01`

variable: FB
type: real variable
description: number of blades of the propeller, converted to integer within the program
example: `4.0`

variable: FTPRP
type: real variable
description: for future use, must use a value of 1.01
example: `1.01`

variable: FTWST
type: real variable
description: for future use, must use a value of 1.01
example: `1.01`

variable: FCOB
type: real variable
description: number of root chord lengths the upstream and downstream boundaries are located at from the pitch change axis
example: `8.0`

variable: FGR
type: real variable
description: control for future use, must use a value of 1.01
example: 1.01

DATA TYPE

variable: DATA TYPE
type: real variable
description: determines the input format for airfoil crossection
example:

1	format is 3f10.6	XUPPER, ZUPPER, ZLOWER
2	format is 6f10.6	XUPPER, ZUPPER, ZLOWER, XUPPER, ZUPPER, ZLOWER
3	format is 10x, 6f10.6	XUPPER, ZUPPER, ZLOWER, XUPPER, ZUPPER, ZLOWER
6	format is 10x, 4f10.6	XUPPER, ZUPPER, XLOWER, ZLOWER

NOTE: The input data set from YW(J) to ZLOWER should be repeated FNC times.

YW(J) AL ALED FAD CHD FSEC THICK

variable: YW(J)
type: real variable
description: span station or radius location
example: 0.191708

variable: AL
type: real variable
description: angle with respect to blade setting angle in degrees
example: 0.0

variable: ALED
type: real variable
description: leading edge alignment
example: 0.01

variable: FAD
type: real variable
description: face alignment
example: -0.01

variable: CHD
type: real variable
description: chord
example: 0.2

variable: FSEC
type: real variable
description: blade geometry parameter
example: 1 section airfoil cross-sections are identical along the blade span
2 section airfoil cross-sections are different along the blade span

variable: THICK
type: real variable
description: control for future use, must use a value of 1.01
example: 1.01

ZSYM FNU FNL

variable: ZSYM
type: real variable
description: symmetry parameter
example: 0 non-symmetric airfoil cross-section
1 symmetric airfoil cross-section

variable: FNU
type: real variable
description: number of points on the upper surface of airfoil, converted to integer within the program
example: 25.0

variable: FNL
type: real variable
description: number of points on the lower surface of airfoil, converted to integer within the program
example: 25.0

NOTE: See input variable DATA TYPE. If ZSYM = 1, input contains only the upper surface definition. Must have FNU sets of data for upper surface and FNL for lower surface.

X ZUPPER ZLOWER

variable: XUPPER
type: real variable
description: chordwise distance from leading edge, normalized with local chord
example: 0.0 .. 1.0

variable: ZUPPER
type: real variable
description: upper surface coordinates corresponding to XUPPER values, normalized with local chord
example: 0.0 .. 0.02

variable: XLOWER
type: real variable
description: chordwise distance from leading edge, normalized with local chord
example: 0.0 .. 1.0

variable: ZLOWER
type: real variable
description: lower surface coordinates corresponding to XLOWER values, normalized with local chord
example: 0.0 .. -0.02

4. DESCRIPTION OF INPUT & OUTPUT FILES

The code uses the following files:

(1) UNIT 2: input file; unformatted file containing externally generated grid. Not required if grid is generated internally.

(2) UNIT 3: input file; formatted file containing blade structural grid. Required only for aeroelastic analysis. See subroutine STRUC0 for details.

(3) UNIT 4: input file; formatted file containing blade generalized mass, natural frequencies and normal mode shapes. Required only for aeroelastic analysis. See subroutine STRUC0 for detail.

(4) UNIT 5 : input file; formatted input file named as ducte3d.inp. Contains information on geometry, grid generation parameters, operating condition and solution control parameters. The file format and input variables have been defined in the previous section.

(5) UNIT 6: output file; formatted file renamed as ducte3d.out. Contains information on grid generation, operating condition of the solution, convergence history and chordwise pressure coefficients.

(6) UNITs 7 & 9: output files; unformatted grid files for plotting program PLOT3D created at the end of the calculations. UNIT 7 contains grid for front row and UNIT 9 for aft row.

(7) UNITs 8 & 10: output files; unformatted aerodynamic solution files for PLOT3D created at the end of the calculations. UNIT 8 contains flow information for front row and UNIT 10 contains for aft row.

(8) UNIT(s) 10+n, $1 \leq n \leq$ NBLOKS: input file(s); unformatted file(s) for restart run. For restart, previous run output files UNIT 30+n are renamed as UNIT 10+n for present run.

(9) UNIT(s) 30+n, $1 \leq n \leq$ NBLOKS: output file(s); unformatted file(s) written at the end of each run. Used for restarting a run.

(10) UNIT 57: output file; formatted file containing variation of normal modes for all blades and all modes used in the analysis. In time domain aeroelastic analysis it contains the time history

of the blade response; in frequency domain it is used as motion input file in Fourier analysis. It has six columns which are iteration count, blade number, time, and blade displacements in the three normal modes. This file is not generated for aerodynamic analysis.

(11) UNITs 93, 94 & 95: output files; formatted file containing generalized force variation with time for all the blades. Each unit contains forces for one mode of analysis. These forces in conjunction with the motion in file UNIT 57 are used in frequency domain flutter analysis. These files have five columns which are, iteration count, blade number, total generalized force, steady generalized force and unsteady generalized force. Unsteady generalized force (fifth column) is used to determine the aeroelastic stability. This file is not generated for aerodynamic analysis.

(12) UNIT 98: output file; formatted file containing the time history information of force coefficients. It has four columns which are iteration count, power coefficient, thrust coefficient and efficiency.

5. ADDITIONAL NOTES

The aerodynamic and aeroelastic analysis assumes the following normalizations: all lengths are normalized by the diameter of the rotor, speeds with the free stream speed of sound and density with free stream density. The input geometry may be prescribed either in non-dimensional quantities normalized by the diameter or in dimensional quantities. If geometry is defined in non-dimensional quantities, the diameter should be defined as 1. For counter rotation geometry, the front rotor diameter is used for normalization. Additional inputs are required for geometry definitions in the case of a counter rotating geometry. The code can also be used to analyze unducted rotors with minor input changes. Detailed description of the inputs and sample run cases for unducted fans are listed in Ref. 5.

6. TEST CASES

Some sample test cases are provided in this section. A brief description of the test case along with input and output file listing is provided. In order to save space several lines from the listings have been deleted. The listings are provided to ensure that the result obtained by the user compares favorably with the listings provided here.

The output listing of UNIT 6 is organized as follows:

The beginning of the output file contains the information regarding the type of solution being obtained, e.g. steady aerodynamic solution, aeroelastic solution, single-rotation fan, counter-rotation fan, etc., followed by the flight conditions.

Geometry input data is then echoed for fresh runs, it is suppressed for restart runs. The maximum and minimum Jacobians follow the geometry input echo. This provides information about the grid. If the maximum and minimum Jacobians have opposite signs, a grid line crossover is indicated and a new grid will have to be generated. This calculation is made only in the first time step.

The residuals are listed next. Maximum absolute change in the density along with the location of this change is printed. At this location, changes in momentum and energy are also listed. These quantities are printed for the first ten iterations and then every 25th iteration beginning from the 26th iteration. Also, every 50th iteration, the average value of the residuals are printed. The solution is stopped any time any one of the maximum residuals become larger than one. The listing of the residuals continue until the maximum number of time steps provided in the input has been reached.

The pressure coefficient for each spanwise station of each blade is printed at the last time step. For the counter-rotation cases, front row pressure coefficients are followed by the listing for aft row. Along with the listing, a line plot of the pressure coefficient variation with the grid streamwise index is also provided for a quick reference.

The power coefficient, thrust coefficient and efficiency are listed next followed by the information about the CPU time and memory used per time step.

The following test cases are provided in this manual:

6.1 Steady aerodynamic analysis of an isolated fan row.
6.2 Time domain aeroelastic analysis of an isolated fan row with eight blades.
6.3 Frequency domain aeroelastic analysis of an isolated fan row with eight blades.

6.1 Steady aerodynamic analysis of an isolated fan row

Description:

In this case an isolated fan row with eight blades is analyzed. The fan geometry is obtained by encasing the standard eight bladed SR3 propfan in a rigid cylindrical duct. For the present analysis the tip gap has been set to 0.4% of the propfan radius. There are no grid points in the radial direction, hence the flow through the gap will not be analyzed, but because of the gap there will be some pressure relief at the tip. The inflow is axial and uniform, with a free stream Mach number of 0.50. The advance ratio is 3.55 and setting angle at blade 75% radius is 61.2°. The convergence is judged by the convergence of time history of the power coefficient. A total of 9000 steps were required to obtain convergence for the present case. The input parameters are provided in the listing of the input. For a steady solution, the input parameter QUASISTEADY should be set to TRUE. Once the AEROELASTIC variable is set to FALSE all other input related to aeroelastic

calculation is ignored. For a restart solution, the UNIT 31 file generated in the previous analysis should be linked to UNIT 11 file of the current analysis and the input variable RESTART should be set to TRUE.

UNIT 5 (ducte3d.inp; input file)

```
SR3-Ducted Propfan, flat plate duct
       ADV        GMU       ALFA        PSI         WW         DT     REYREF
    3.5500        0.0        0.0        0.0        7.0      .0030       -1.0
      IMAX       JMAX       KMAX       JTIP       ITEL        ILE      INOSE
       100         21         16         20         30         36         16
      FSTP      FMINF     BETA34        DIA         DX         DZ     VIBFRE
    9000.0      0.500      61.20        1.0       0.01      0.030        1.8
      ICCW       IFAN      ITURB      LTHIN        IGR       ISWF
         1          1          0          0          0          0
        P0         T0         A0     PRATIO
    14.700     528.00   13040.00      1.000
RESTART,QUASISTEADY,INFLOW,AEROELASTIC,COUNTER ROTATION,RESABD AND DUCT
FALSE TRUEFALSEFALSEFALSEFALSE TRUE
     IFLTR     NUMCYC      NSTDY      JMODE     NBLOKS
        -1          0          2          3          1
   FNRS
   60.01
    XR         RR
 -0.295920  0.010000
 -0.287760  0.014857
 -0.279590  0.022857
 -0.271430  0.029796
......
```

*** Several lines of hub geometry definition deleted ***

```
......
  0.661220  0.154650
  0.700000  0.154650
  0.800000  0.154650
  1.099999  0.154650
      XLED       ZLED      CHORD    ----- PARAMETERS FOR THE COWL
     -0.25      0.505        0.5
FSYM,FNU,FNL
  1.0       33.0       33.0
     X          Y
   0.00000    0.00000
    .02500     .05765
    .06250     .09470
    .12500     .13075
    .25000     .17775
......
```

*** Several lines of duct geometry definition deleted ***

```
......
   4.00000     .13115
   4.25000     .10275
   4.50000     .07240
   4.75000     .04035
   5.00000     .00630
  INASTRAN
         0
```

```
      FNC     FROTAT         FB      FTPRP      FTWST       FCOB       FGR
     13.0       1.01        8.0       1.01       1.01         8.      1.01
DATA TYPE
     2.05
    YW(J)         AL       ALED        FAD        CHD       FSEC     THICK
  0.00000   33.01000   -0.02075    0.00000    0.16695   1.000000      1.00
     ZSYM        FNU        FNL
 0.000000  25.000000  25.000000
        X     ZUPPER     ZLOWER
 0.000000   0.000000   0.000000   0.043924   0.027370  -0.027239
 0.085493   0.038369  -0.039117   0.126746   0.048135  -0.050491
 0.167928   0.056366  -0.060960   0.209243   0.063894  -0.071346
 0.250325   0.070800  -0.081508   0.291401   0.077129  -0.091354
 0.332469   0.082918  -0.100846   0.373520   0.088131  -0.109802
 0.414583   0.092607  -0.117979   0.455679   0.096111  -0.124962
 0.496797   0.098159  -0.130168   0.537985   0.098408  -0.133133
 0.579236   0.096783  -0.133664   0.620573   0.093367  -0.131732
 0.662011   0.088250  -0.127295   0.703559   0.081441  -0.120175
 0.745148   0.073052  -0.110456   0.786971   0.063141  -0.098069
 0.829177   0.052067  -0.083190   0.871426   0.040052  -0.065918
 0.913613   0.027690  -0.046729   0.956337   0.014398  -0.024961
 1.000000   0.000000   0.000000
    YW(J)         AL       ALED        FAD        CHD       FSEC     THICK
```

......

*** Several sets of blade geometry definition deleted ***

......

```
    YW(J)         AL       ALED        FAD        CHD       FSEC     THICK
  0.50004   -7.85471    0.10204    0.00164    0.07007   1.000000      1.00
     ZSYM        FNU        FNL
 0.000000  25.000000  25.000000
        X     ZUPPER     ZLOWER
 0.000000   0.000000   0.000000   0.045021   0.006198  -0.001988
 0.088813   0.009473  -0.001168   0.131787   0.012711  -0.000386
 0.175385   0.015168   0.000824   0.217988   0.017158   0.001177
 0.260786   0.019148   0.001959   0.303389   0.020749   0.002702
 0.345622   0.021492   0.002627   0.387620   0.022625   0.003370
 0.429638   0.023369   0.003685   0.471071   0.023255   0.003572
 0.513108   0.023570   0.003496   0.554346   0.023457   0.002955
 0.595993   0.022953   0.002841   0.636626   0.021983   0.002689
 0.677473   0.021012   0.002147   0.718321   0.019652   0.001996
 0.758973   0.017863   0.001844   0.799664   0.015256   0.000874
 0.839498   0.013429   0.000684   0.879974   0.010393   0.000532
 0.920041   0.007747  -0.000048   0.959719   0.003854  -0.000238
 1.000000   0.000000   0.000000
```

UNIT 6 (duct3d.out; output file)

```
1     SR3-Ducted Propfan, flat plate duct
 *******************************************************
 *                                                     *
 *              STEADY EULER ANALYSIS                  *
 *                 DUCTED PROPELLER                    *
 *                                                     *
 *******************************************************
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ---------------------------------------
 +  pressure=14.69999999999999
 +  speed of sound (in/sec)=13040.
```

```
+  density=1.210292069705291E-7
++++++++++++++++++++++++++++
*    operating conditions:
----------------------------------------
*  rotor speed(rpm)=0.
*  rotor speed(rad/sec)=0.
*  Mach no.= 0.5
*  advance ratio (J).= 3.549999999999997
*  tip radius (inches)=0.5
----------------------------------------

NOT A RESTART, NO INITIAL SOLUTION.
 FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
 CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
 RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
 CHARACTERISTICS USED TO UPDATE UPSTREAM BOUNDARY
     IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
     IJDIS =    2
     IKDIS =    1
     IJ2   =    0
     IIDIS =    1
     IHPQ  =    1
     WWY COEFFICIENT IN DIS2 IS =1.
     ICHAR IN JBC =1
     IN WALLBC THE CONSTANTS ARE :
     IWHIT =    0
     INL  =    1
     IEX   =    2
     JEX   =    1
     INRES =0
     IHORD =0
     KHORD =0
     ISMTH =0
     KSMTH =0
     IVIBR =0
       WWF =100.

    IMAX=       100
    JMAX=        21
    KMAX=        16
    JTIP=        20
    ITEL=        71
    ILE =        36
    INOSE=        16
    NSTEP=      9000
     DX =          0.01000000
     DZ =          0.03000000
      DT=          0.00300000
      WW=          7.00000000
    ALFA=          0.00000000
   AMTIP=          0.44247784
    FMINF=          0.50000000
    ADVANCE RATIO =    3.55000000
    vibration freq. =    0.00000000
    VIBRATING IN    3  MODE


     GMU=          0.00000000


     PSI=          0.00000000
 **** NSTDY =0
 **** JMODE =3
```

```
cosa=1. sina=0.
   Y(  1) =      0.0000
   Y(  2) =      0.0300
   Y(  3) =      0.0700
......
```

*** Several lines deleted ***

```
......
   Y( 19) =      0.9920
   Y( 20) =      1.0000
   Y( 21) =      1.0100
 No. OF RADIAL STATIONS ON BODY = 62
    INPUT AIRFOIL GEOMETRY


         X          Y


 CHORD =5. XP(N)=5. XP(NL) =0.
 WSURFR CRDCWL=0.5
 xled =-0.25 zled=0.5019999999999989
   1     1.0000     0.0000
   2     0.9500     0.0000
   3     0.9000     0.0000
......
```

*** Several lines deleted ***

```
......
  63     0.9000     0.0000
  64     0.9500     0.0000
  65     1.0000     0.0000
   1     0.2500     0.5020
   2     0.2250     0.5020
   3     0.2000     0.5020
......
```

*** Several lines deleted ***

```
......
  31    -0.2438     0.5020
  32    -0.2475     0.5020
  33    -0.2500     0.5020
 ILE=65 NSURF=36
 XLOC =0. INAS =0
  NBLADS=8
     IGR=1
    ITPR=1
    ITWS=1
     THT=44.99999991709956
    IROT=1
  DATA TYPE=2
     DIA1 = 1.
 BETA=61.20000000000005deg
 PMB2=-0.502654822032234    IN DEGRESS = -28.79999988725524
 INPUT WING GEOMETRY


 PROFILE AT Y =     0.00000
     XLE             ZLE            CHORD     THICKNESS FACTOR      ALPHA
    -0.0174          0.0113          0.1669         1.0000          0.5761
 INPUT WING GEOMETRY
```

••••••

*** Several output lines of input data echo deleted ***

••••••

```
 PROFILE AT Y =     0.50004
      XLE              ZLE             CHORD     THICKNESS FACTOR     ALPHA
      0.1009           0.0156           0.0701           1.0000        -0.1371
   DELTA BETA AT 75% SPAN IS =2.347735298443332E-2
  irow=1 irc=1
  SPAN=0.5000399999999985 YWN =0.5000399999999985
  PB =6.274619684608354 J=1
  PB =6.274619684608354 J=1
  PB =6.383875993673456 J=2
  PB =6.383875993673456 J=2
```

••••••

*** Several lines deleted ***

••••••

```
  PB =35.51974285755659 J=19
  PB =35.51974285755659 J=19
  PB =35.56532434234305 J=20
  PB =35.56532434234305 J=20
  xledd=-0.25 rledd=0.5019999999999989 xted=0.2499999999999982 rted=0.5019999999999989 nd=35
  xrd rld 10.,  0.5019999999999989,  0.2499999999999982,  0.5019999999999989,  0.2249999999999996,
0.5019999999999989,
 0.1999999999999993,       0.5019999999999989,       0.1749999999999989,       0.5019999999999989,
0.1499999999999986,  0.5019999999999989,


 -0.2375000000000007,     0.5019999999999989,     -0.2437500000000004,     0.5019999999999989,     -
0.2475000000000005,  0.5019999999999989,
 -0.25,  0.5019999999999989,  -10.,  0.5019999999999989
  xg=9.891054401272692E-2   yg=0.4962293376645182   zg=7.589759179996535E-2   rry=0.5019999999999989
rtip=0.4999992006432432,  21
  ygl=0.4962293376645182 ygt=0.4943035280608861 ygtu=0.4941059677291761 zgtu=7.654071180186328E-2
  xr=1.965719937435793 rr=0.1546500000000002
  xr=1.099998999999997 rr=0.1546500000000002
```

••••••

*** Several lines deleted ***

••••••

```
  xr=-0.2959200000000006 rr=1.E-2
  xr=-1.965719937435793 rr=1.E-2
  rlet=0.4999377372134752 rled=0.5019999999999989 i=1
  rlet=0.4999377372134752 rled=0.5019999999999989 i=2
```

••••••

*** Several lines deleted ***

••••••

```
  rlet=0.4992299179370807 rled=0.5019999999999989 i=99
  rlet=0.4992299179370825 rled=0.5019999999999989 i=100
  rlet=0.5   rled=0.5019999999999989   rtet=0.5   rted=0.5019999999999989   rledf=1.999999999998891E-3
rtedf=1.999999999998891E-3
  J=1 CHORD=0.1638099947863161
  J=2 CHORD=0.1660150864596632
```

••••••

*** Several lines deleted ***

```
......
  J=20 CHORD=7.387989523808835E-2
  J=21 CHORD=7.387724509185789E-2
  wingeo done ytipd=0.5
  TOTAL NUMBER OF STEPS  9000
  reyref=-1000000. reynum=0.
  entering INITQ
  FMINF=0.5 SMINF=0. ICBU=16 ICBD=100
  imax=100 jmax=21 kmax=15 ngp=27720
  MAX JACOB=7.999591762997441E-5 MIN JACOB=8.441722412160079E-9 AT 20
  IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
  MAX JACOB=1.151533809000812E-4 MIN JACOB=1.291499186892988E-8 AT 19
  IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
......
```

*** Several lines of Jacobian output deleted ***

```
......
  MAX JACOB=7.990930163025242E-5 MIN JACOB=1.406906985244854E-7 AT 3
  IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14
  MAX JACOB=5.501060715913598E-5 MIN JACOB=1.043742011267831E-7 AT 2
  IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14

    DRMAX       DUMAX       DVMAX       DWMAX       DEMAX       IB    IROW   IR   JR   KR
    0.1006E-16  0.3290E-16  0.2327E-16  0.6339E-17  0.2941E-15        1    1   11    2   11
    0.1919E-01  0.3520E-02  0.3838E-02  0.4655E-02  0.4827E-01        1    1   74    2    9
    0.1844E-01  0.4586E-02  0.5098E-02  0.6060E-02  0.4596E-01        1    1   74    2    9
    0.1702E-01  0.5733E-02  0.6969E-02  0.6905E-02  0.4299E-01        1    1   74    2    9
    0.1674E-01  0.7202E-02  0.7913E-02  0.7725E-02  0.4300E-01        1    1   48    2   14
    0.1601E-01  0.8115E-02  0.9166E-02  0.8097E-02  0.4088E-01        1    1   49    2   14
    0.1552E-01  0.9360E-02  0.9623E-02  0.8554E-02  0.4029E-01        1    1   49    2   14
    0.1468E-01  0.9878E-02  0.1036E-01  0.8672E-02  0.3791E-01        1    1   49    2   14
    0.1394E-01  0.1085E-01  0.1041E-01  0.8925E-02  0.3673E-01        1    1   49    2   14
    0.1303E-01  0.1100E-01  0.1072E-01  0.8902E-02  0.3416E-01        1    1   49    2   14
    0.8443E-02  0.9337E-02  0.5973E-02  0.6438E-02  0.2297E-01        1    1   70    3    2
  AVERAGE RESIDUES --  0.70619E-03  0.55029E-03  0.47197E-03  0.37372E-03  0.17194E-02      50
    0.8646E-02  0.6238E-02  0.5518E-02  0.2748E-02  0.2307E-01        1    1   65    5    2
    0.5634E-02  0.5314E-02  0.7428E-02  0.3295E-02  0.1537E-01        1    1   84   20   12
  AVERAGE RESIDUES --  0.60366E-03  0.43154E-03  0.38030E-03  0.24536E-03  0.15486E-02     100
......
```

*** Several output lines deleted ***

```
......
  AVERAGE RESIDUES --  0.91947E-05  0.91663E-04  0.60043E-04  0.57420E-06  0.23476E-04    8950
    0.9133E-04  0.5086E-03  0.5118E-03  0.1087E-04  0.2352E-03        1    1   87   19    5
    0.9133E-04  0.4869E-03  0.5071E-03  0.9671E-05  0.2351E-03        1    1   87   19    5
    0.9134E-04  0.4799E-03  0.5098E-03  0.9703E-05  0.2351E-03        1    1   87   19    5
  AVERAGE RESIDUES --  0.92855E-05  0.93271E-04  0.59862E-04  0.56628E-06  0.23554E-04    9000
     ISTP= 9000     IB =    1     IROW =    1     TIME =    27.0000


     J=     1     Y=    0.2431     CL=    0.0057     CD=    0.1476     CM=    0.0143


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.3222  0.3222                           *         I
 -0.0709  0.0093  0.0107  0.8657 -0.0683          *                          I +
 -0.0692  0.0198  0.0227  0.6316 -0.3675                 *                   I          +
 -0.0672  0.0317  0.0363  0.6064 -0.2942                   *                 I        +
 -0.0649  0.0450  0.0516  0.3564 -0.6833                          *          I                    +
 -0.0624  0.0606  0.0682  0.3679 -0.4755                          *          I             +
 -0.0595  0.0781  0.0868  0.2955 -0.4562                            *        I             +
```

```
 -0.0563  0.0980  0.1079  0.2792 -0.3438                           *       I         +
 -0.0527  0.1203  0.1315  0.2447 -0.2630                            *      I       +
 -0.0487  0.1455  0.1581  0.2226 -0.1766                            *      I    +
 -0.0441  0.1739  0.1881  0.1919 -0.1166                             *     I   +
 -0.0389  0.2059  0.2218  0.1376 -0.1088                               *   I  +
 -0.0331  0.2419  0.2597  0.0515 -0.1581                                 * I    +
 -0.0260  0.2864  0.3065 -0.0505 -0.2102                                   I *   +
 -0.0188  0.3310  0.3533 -0.1437 -0.2366                                   I   *  +
 -0.0116  0.3756  0.3999 -0.2114 -0.2505                                   I     * +
 -0.0045  0.4203  0.4463 -0.2485 -0.2608                                   I      *+
  0.0027  0.4654  0.4923 -0.2359 -0.2367                                   I      *
  0.0098  0.5113  0.5376 -0.1829 -0.1780                                   I    +*
  0.0170  0.5578  0.5823 -0.1450 -0.1383                                   I   *
  0.0241  0.6044  0.6267 -0.1466 -0.1383                                   I   *
  0.0313  0.6511  0.6709 -0.1420 -0.1355                                   I   *
  0.0384  0.6978  0.7149 -0.1229 -0.1181                                   I   *
  0.0455  0.7443  0.7591 -0.0942 -0.0921                                   I  *
  0.0513  0.7819  0.7948 -0.0681 -0.0629                                   I *
  0.0564  0.8154  0.8263 -0.0448 -0.0408                                   I*
  0.0609  0.8452  0.8543 -0.0268 -0.0252                                   I*
  0.0649  0.8716  0.8791 -0.0096 -0.0083                                   *
  0.0685  0.8950  0.9012  0.0092  0.0114                                   *
  0.0717  0.9158  0.9208  0.0317  0.0335                                  *I
  0.0745  0.9343  0.9382  0.0572  0.0637                                 * I
  0.0770  0.9508  0.9536  0.0898  0.0954                                *  I
  0.0792  0.9653  0.9674  0.1200  0.1353                               *   I
  0.0812  0.9783  0.9795  0.1571  0.1745                              *    I
  0.0829  0.9898  0.9904  0.1893  0.2228                            +*     I
  0.0845  1.0000  1.0000  0.2307  0.2671                           +*      I


     J=      2      Y=     0.2642      CL=  -0.0002      CD=    0.1479      CM=    0.0102


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL    X/CU     CPL     CPU
 -0.0784  0.0000  0.0000  0.3196  0.3196                         *         I
 -0.0768  0.0093  0.0107  0.8588 -0.0677         *                         I +
 -0.0750  0.0198  0.0227  0.6265 -0.3645                *                  I          +
```

......

*** Several lines deleted ***

```
  0.0781  0.9784  0.9793  0.1557  0.1730                              *    I
  0.0799  0.9898  0.9903  0.1877  0.2209                            +*     I
  0.0814  1.0000  1.0000  0.2287  0.2648                           +*      I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
     J=     20      Y=     1.0000      CL=   0.2824      CD=    0.3689      CM=    0.0057


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000 -0.3187 -0.3187                              I         *
  0.0771  0.0088  0.0103  0.3593 -0.9400                    *         I                            +
```

......

*** Several lines deleted ***

```
••••••
   0.1350  0.9769  0.9785  0.1083  0.0172                                  *  +
   0.1357  0.9892  0.9899  0.1113  0.0277                                  *  +
   0.1363  1.0000  1.0000  0.1175  0.0349                                  * +I
    FOR THE SINGLE ROTATION PROPFAN :
      ADVANCE RATIO =          3.55000000
      POWER COEFFICIENT =      1.90484470
      THRUST COEFFICIENT =    0.12226586
      EFFICIENCY =             0.22786308
 inlet mach no.=   0.477 u= -0.0001 v=  0.0000 w= -0.4770 ql=  1.0159 p=  0.7302 r=  0.01000 j=  1
 exit mach no.=   0.471 u= -0.0315 v=  0.0354 w= -0.4688 ql=  1.0350 p=  0.7143 r=  0.15465 j=  1
 inlet mach no.=   0.484 u= -0.0015 v= -0.0018 w= -0.4842 ql=  1.0159 p=  0.7302 r=  0.02469 j=  2
 exit mach no.=   0.487 u= -0.0271 v=  0.0403 w= -0.4843 ql=  1.0350 p=  0.7143 r=  0.16501 j=  2
••••••
```

*** Several lines deleted ***

```
••••••
 inlet mach no.=   0.478 u=  0.0042 v=  0.0038 w= -0.4781 ql=  1.0231 p=  0.7371 r=  0.49923 j= 20
 exit mach no.=   0.583 u= -0.0343 v=  0.0847 w= -0.5763 ql=  0.9526 p=  0.7143 r=  0.49994 j= 20
 inlet mach no.=   0.466 u= -0.0072 v= -0.0101 w= -0.4661 ql=  1.0231 p=  0.7371 r=  0.50200 j= 21
 exit mach no.=   0.589 u= -0.0578 v=  0.0600 w= -0.5830 ql=  0.9526 p=  0.7143 r=  0.50200 j= 21
  Relative Mach No. at Tip =0.8804315670821552
  Relative Mach No. at Tip (Mid Plane)=0.6552434844609003
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  The Following Quantities are at I =5 Z=1.102164637904551
  Mass Flow Rate =-0.236207591324586 (lb/s) Corrected =-0.2383157187171419 (lb/s @ 518.7R & 14.7psi)
  The Following Quantities are at I =50 Z=2.053126919559777E-2
  Mass  Flow  Rate  =-0.2181974900088424  (lb/s)  Corrected  =-0.2201448791807783  (lb/s  @  518.7R  &
14.7psi)
  The Following Quantities are at I =95 Z=-0.8030763509607972
  Mass Flow Rate =-0.2353509986381255 (lb/s) Corrected =-0.237451481032922 (lb/s @ 518.7R & 14.7psi)
       TIME/ITERATION =0.6035743442960921
```

UNIT 98 (Output file; contains performance characteristics)

```
 itn      cpwr               cth                 eff
 2,  0.3757886854022896,  -0.2409143621258414,  -2.275869441442012
 3,  0.7486666951962384,  -0.1736646325623257,  -0.8234765210634336
 4,  1.113009184348662,  -0.1078720917114397,  -0.3440635809305661
 5,  1.467452655071085,  -4.378041892827155E-2,  -0.1059117557614391

••••••
```

*** 8990 lines of output deleted ***

```
••••••
 8996,  1.90484801441329,  0.1222669469884616,  0.227864721240099
 8997,  1.904934806776126,  0.1222928662365859,  0.2279026419148735
 8998,  1.904846353133664,  0.1222664061727965,  0.2278639120679626
 8999,  1.904933130402085,  0.1222923155162321,  0.2279018161603332
 9000,  1.904844699655435,  0.1222658555353049,  0.2278630836565565
```

6.2 Time Domain Aeroelastic Analysis of an Isolated Fan Row

Description:

A test case for an aeroelastic stability analysis using time domain method is provided here. The fan analyzed has eight blades and the first three normal modes are included in the analysis. A steady solution is first generated using the sample case provided in 6.1 for the desired flow conditions. The aeroelastic analysis is then carried out by restarting the analysis from the steady solution. In order to carry out the aeroelastic analysis, the structural grid (UNIT 3) and structural mode shapes (UNIT 4), are needed. The input file for this analysis is very similar to the steady analysis with changes in the lines shown below in the input file **ducte3d.inp**. The input variables `RESTART` and `AEROELASTIC` are set to `TRUE`, `IFLTR` to a negative integer and `NBLOKS` to 8. The variables that need to be changed are indicated in **bold** print. All other input parameters remain the same as used in the steady aerodynamic analysis. The example given here was restarted from the steady solution presented in section 6.1 and was obtained by running the code for 9000 time steps with `dt=0.003`.

For starting the aeroelastic solution, the file generated on `UNIT 31` in the steady analysis is linked to `UNIT 11` for the current analysis. For an aeroelastic restart, i.e. restarting the solution from a previous aeroelastic solution, the only change required is to link the files generated on `UNITs 30+n` by the previous aeroelastic analysis to `UNITs 10+n` for the current analysis. Since, the time domain analysis method is used, any number of normal modes can be included in the analysis.

In addition to `UNIT 98`, additional output files are generated in this analysis. The file linked to `UNIT 57` contains the time history of the normal mode displacements for all the modes and all the blades included in the analysis. The variation of normal modes provides the aeroelastic stability of the propeller. An increasing oscillation amplitude indicates instability. The interblade phase angle can be assessed from the time history of the normal modes. The other files generated do not contain any useful information and can be ignored.

UNIT 5 (ducte3d.inp; input file)

```
SR3D Only one direction marching (from root to tip)

.....

*** same as steady aerodynamic input, see section 6.1 ***

.....
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD, DUCT
 TRUE TRUEFALSE TRUEFALSEFALSE TRUE
    IFLTR    NUMCYC     NSTDY     JMODE    NBLOKS
       -1         0         2         1         8
    FNRS

.....

*** same as steady aerodynamic input, see section 6.1 ***
.....
```

UNIT 6 (duct3d.out; output file)

```
1     SR3-Ducted Propfan, flat plate duct
 *******************************************************
 *       aeroelastic stability analysis               *
 *     using normal mode structural model             *
 *       with Euler aerodynamic model in              *
 *                TIME DOMAIN                         *
 *******************************************************

 -------------------------------------------------------
        Interblade Phase Angle =45. Degrees
 -------------------------------------------------------

 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.69999999999999
 +  speed of sound (in/sec)=13040.
 +  density=1.210292069705291E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=0.
 *  rotor speed(rad/sec)=0.
 *  Mach no.= 0.5
 *  advance ratio (J).= 3.549999999999997
 *  tip radius (inches)=0.5
 ----------------------------------------

 RESTART RUN FROM A PREVIOUS SOLUTION
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  CHARACTERISTICS USED TO UPDATE UPSTREAM BOUNDARY
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =    2
      IKDIS =    1
      IJ2   =    0
      IIDIS =    1
      IHPQ  =    1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
      IWHIT =    0
      INL  =    1
      IEX   =    2
      JEX   =    1
      INRES =0
      IHORD =0
      KHORD =0
      ISMTH =0
      KSMTH =0
      IVIBR =1
        WWF =100.


     IMAX=       100
     JMAX=        21
     KMAX=        16
     JTIP=        20
     ITEL=        71
     ILE =        36
     INOSE=        16
     NSTEP=      8000
```

```
     DX =          0.01000000
     DZ =          0.03000000
      DT=          0.00300000
      WW=          7.00000000
    ALFA=          0.00000000
   AMTIP=          0.44247784
    FMINF=          0.50000000
    ADVANCE RATIO =   3.55000000
    vibration freq. =   1.80000000
    VIBRATING IN    3  MODE


     GMU=          0.00000000
 **** NSTDY =2
 **** JMODE =3
 cosa=1. sina=0.
 TOTAL NUMBER OF STEPS  8000
 reyref=-1000000. reynum=0.
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
 MAX JACOB=7.999591762776047E-5 MIN JACOB=8.441722412234353E-9 AT 20
 IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
 MAX JACOB=1.151533808997819E-4 MIN JACOB=1.291499186729728E-8 AT 19
 IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
```

......

*** Several lines of Jacobian output deleted ***

......

```
 MAX JACOB=7.990930162917559E-5 MIN JACOB=1.406906985237722E-7 AT 3
 IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14
 MAX JACOB=5.501060715851278E-5 MIN JACOB=1.043742011269572E-7 AT 2
 IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14

   DRMAX        DUMAX        DVMAX        DWMAX        DEMAX        IB     IROW    IR    JR    KR
   0.9133E-04  0.4960E-03  0.5190E-03  0.1082E-04  0.2352E-03        1     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.4793E-03  0.4699E-03  0.1087E-04  0.2352E-03        2     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.5190E-03  0.4960E-03  0.1089E-04  0.2352E-03        3     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.4699E-03  0.4791E-03  0.1089E-04  0.2352E-03        4     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.4960E-03  0.5190E-03  0.1086E-04  0.2352E-03        5     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.4793E-03  0.4699E-03  0.1083E-04  0.2352E-03        6     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.5190E-03  0.4960E-03  0.1089E-04  0.2352E-03        7     1    87    19     5
 FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
 imax=100 jmax=21 kmax=15 ngp=27720
   0.9133E-04  0.4699E-03  0.4791E-03  0.1086E-04  0.2352E-03        8     1    87    19     5
 READING NASTRAN DATA: GRID COORDINATES
DIAMET = 25.12798087312228
BETGRD = 60.51058046349885DBET =-0.6894195793147446
MODAL DISPLACEMENTS: MODE 1
GMASS =2.408412999999997E-5 FREQ(hz) =221.0820000000003
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 2
```

```
GMASS =2.444044E-5 FREQ(hz) =402.1286999999993
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 3
GMASS =1.445758000000001E-5 FREQ(hz) =698.2001999999993
FINISHED READING NASTRAN DATA
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
*  tip radius for structural model (inches)=12.56399043656114
Newmark constants
     0.50000E+00    0.25000E+00
     0.44444E+06    0.66667E+03
     0.13333E+04    0.10000E+01
     0.10000E+01    0.00000E+00
     0.15000E-02    0.15000E-02
*  airmas            =4.825258216178407E-2
        analysis using 3    modes:

                   structural model
 mode    freq(hz)    gen. mass
----------------------------------------
  1        221.08       0.2408E-04
  1          2.68       0.4991E-03
  2        402.13       0.2444E-04
  2          4.87       0.5065E-03
  3        698.20       0.1446E-04
  3          8.45       0.2996E-03
----------------------------------------
 mass, damping and stiffness matrices
----------------------------------------
     0.49913E-03    0.00000E+00
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.00000E+00
     0.35763E-02    0.00000E+00
     0.00000E+00
     0.00000E+00    0.50651E-03
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.00000E+00
     0.00000E+00    0.12007E-01
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.29962E-03
     0.00000E+00   .0.00000E+00
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.21412E-01
     0.20035E+04    0.00000E+00
     0.00000E+00
     0.45078E-02    0.00000E+00
     0.00000E+00
     0.00000E+00    0.19743E+04
     0.00000E+00
     0.00000E+00    0.44419E-02
```

```
      0.00000E+00
      0.00000E+00    0.00000E+00
      0.33375E+04
      0.00000E+00    0.00000E+00
      0.75082E-02
      finished job in routine strdat
 NUMBER OF TIME STEPS FOR ONE REVOLUTION =  2366
    0.9128E-04  0.4792E-03  0.5099E-03  0.1789E-04  0.2352E-03        1    1   87   19    5
    0.9134E-04  0.4780E-03  0.4589E-03  0.9718E-05  0.2351E-03        2    1   87   19    5
    0.9134E-04  0.5099E-03  0.4792E-03  0.9718E-05  0.2351E-03        3    1   87   19    5
    0.9134E-04  0.4589E-03  0.4783E-03  0.9721E-05  0.2351E-03        4    1   87   19    5
    0.9134E-04  0.4792E-03  0.5099E-03  0.9718E-05  0.2351E-03        5    1   87   19    5
    0.9134E-04  0.4781E-03  0.4589E-03  0.9708E-05  0.2351E-03        6    1   87   19    5
    0.9134E-04  0.5099E-03  0.4792E-03  0.9717E-05  0.2351E-03        7    1   87   19    5
    0.9266E-04  0.4589E-03  0.4780E-03  0.1294E-04  0.2375E-03        8    1   75   19   12
```

......

*** Several lines deleted ***

......

```
    0.1001E-03  0.4701E-03  0.5106E-03  0.5461E-04  0.2498E-03        1    1   57   19    3
    0.9166E-04  0.4786E-03  0.4549E-03  0.9770E-05  0.2358E-03        2    1   87   19    5
    0.9133E-04  0.5106E-03  0.4702E-03  0.9766E-05  0.2351E-03        3    1   87   19    5
    0.9134E-04  0.4549E-03  0.4789E-03  0.9768E-05  0.2351E-03        4    1   87   19    5
    0.9134E-04  0.4702E-03  0.5106E-03  0.9770E-05  0.2351E-03        5    1   87   19    5
    0.9134E-04  0.4787E-03  0.4549E-03  0.9761E-05  0.2351E-03        6    1   87   19    5
    0.9133E-04  0.5106E-03  0.4702E-03  0.9750E-05  0.2351E-03        7    1   87   19    5
    0.9022E-04  0.4548E-03  0.4782E-03  0.6855E-04  0.2335E-03        8    1   96   19    5
  AVERAGE RESIDUES --  0.10422E-04  0.94427E-04  0.59368E-04  0.23709E-05  0.26136E-04     50
  AVERAGE RESIDUES --  0.93903E-05  0.76885E-04  0.72796E-04  0.51911E-06  0.23695E-04     50
  AVERAGE RESIDUES --  0.93397E-05  0.60382E-04  0.93388E-04  0.55192E-06  0.23579E-04     50
  AVERAGE RESIDUES --  0.93426E-05  0.72811E-04  0.76893E-04  0.55018E-06  0.23586E-04     50
  AVERAGE RESIDUES --  0.93426E-05  0.93389E-04  0.60382E-04  0.55025E-06  0.23586E-04     50
  AVERAGE RESIDUES --  0.93425E-05  0.76891E-04  0.72811E-04  0.55001E-06  0.23586E-04     50
  AVERAGE RESIDUES --  0.93478E-05  0.60385E-04  0.93383E-04  0.54852E-06  0.23600E-04     50
  AVERAGE RESIDUES --  0.86257E-05  0.74324E-04  0.76505E-04  0.17039E-05  0.21686E-04     50
```

......

*** Several lines deleted ***

......

```
  AVERAGE RESIDUES --  0.12508E-04  0.68796E-04  0.82139E-04  0.10539E-04  0.30912E-04   7950
  AVERAGE RESIDUES --  0.11258E-04  0.61095E-04  0.93969E-04  0.10654E-04  0.26676E-04   7950
  AVERAGE RESIDUES --  0.14379E-04  0.80000E-04  0.70202E-04  0.74903E-05  0.36416E-04   7950
  AVERAGE RESIDUES --  0.84930E-05  0.91446E-04  0.61047E-04  0.43891E-05  0.20800E-04   7950
  AVERAGE RESIDUES --  0.96556E-05  0.70421E-04  0.81208E-04  0.61106E-05  0.24255E-04   7950
  AVERAGE RESIDUES --  0.15393E-04  0.59245E-04  0.90663E-04  0.75361E-05  0.38168E-04   7950
  AVERAGE RESIDUES --  0.89042E-05  0.83294E-04  0.69165E-04  0.65000E-05  0.22093E-04   7950
  AVERAGE RESIDUES --  0.13298E-04  0.93682E-04  0.58869E-04  0.78136E-05  0.33323E-04   7950
    0.2186E-03  0.5275E-03  0.4764E-03  0.2001E-03  0.4253E-03        1    1   36   19    2
    0.2057E-03  0.5229E-03  0.5073E-03  0.2583E-03  0.3591E-03        2    1   36   20    2
    0.2290E-03  0.4785E-03  0.4538E-03  0.2527E-03  0.4494E-03        3    1   36   20    2
    0.1063E-03  0.5069E-03  0.5124E-03  0.2112E-03  0.2737E-03        4    1   76   19   12
    0.9918E-04  0.4570E-03  0.4789E-03  0.3323E-03  0.2525E-03        5    1   85   19    4
    0.1919E-03  0.5113E-03  0.5066E-03  0.2416E-03  0.3848E-03        6    1   36   20    2
    0.1187E-03  0.4763E-03  0.5489E-03  0.2836E-03  0.3118E-03        7    1   73   19   12
    0.1103E-03  0.5072E-03  0.5222E-03  0.2679E-03  0.2567E-03        8    1   79   19    3
    0.1167E-03  0.5503E-03  0.4603E-03  0.2063E-03  0.2690E-03        1    1   69   19    3
    0.2208E-03  0.5182E-03  0.4842E-03  0.2654E-03  0.4349E-03        2    1   36   20    2
    0.1545E-03  0.4621E-03  0.4572E-03  0.2416E-03  0.2841E-03        3    1   36   20    2
    0.1413E-03  0.4841E-03  0.5093E-03  0.2166E-03  0.2972E-03        4    1   36   20    2
    0.1070E-03  0.4547E-03  0.4629E-03  0.3359E-03  0.2704E-03        5    1   80   19   12
```

```
  0.1294E-03  0.5060E-03  0.4841E-03  0.2480E-03  0.2732E-03        6    1   36   20    2
  0.2342E-03  0.4609E-03  0.5613E-03  0.2973E-03  0.4833E-03        7    1   36   20    2
  0.1244E-03  0.4842E-03  0.5151E-03  0.2662E-03  0.3245E-03        8    1   74   19   12
  0.1100E-03  0.5845E-03  0.4554E-03  0.2193E-03  0.2703E-03        1    1   69   19    3
AVERAGE RESIDUES --  0.97012E-05  0.72323E-04  0.79942E-04  0.80464E-05  0.24133E-04   8000
  0.1685E-03  0.5196E-03  0.4762E-03  0.2767E-03  0.3248E-03        2    1   36   19    2
AVERAGE RESIDUES --  0.11450E-04  0.60001E-04  0.95678E-04  0.90727E-05  0.27893E-04   8000
  0.1290E-03  0.4577E-03  0.4830E-03  0.2356E-03  0.2767E-03        3    1   36   20    2
AVERAGE RESIDUES --  0.13743E-04  0.75930E-04  0.73444E-04  0.78424E-05  0.34488E-04   8000
  0.1584E-03  0.4761E-03  0.5135E-03  0.2263E-03  0.3278E-03        4    1   36   20    2
AVERAGE RESIDUES --  0.84989E-05  0.93635E-04  0.60963E-04  0.52355E-05  0.20417E-04   8000
  0.1089E-03  0.4476E-03  0.4588E-03  0.3437E-03  0.2771E-03        5    1   79   19   12
AVERAGE RESIDUES --  0.10588E-04  0.74576E-04  0.75682E-04  0.51431E-05  0.26960E-04   8000
  0.1183E-03  0.5087E-03  0.4794E-03  0.2538E-03  0.2675E-03        6    1   36   20    2
AVERAGE RESIDUES --  0.14380E-04  0.59892E-04  0.91212E-04  0.84383E-05  0.35487E-04   8000
  0.2638E-03  0.4564E-03  0.5467E-03  0.3164E-03  0.5363E-03        7    1   36   20    2
AVERAGE RESIDUES --  0.10164E-04  0.79982E-04  0.73428E-04  0.88942E-05  0.24580E-04   8000
  0.1221E-03  0.4760E-03  0.5148E-03  0.2678E-03  0.3217E-03        8    1   72   19   12
AVERAGE RESIDUES --  0.16395E-04  0.93497E-04  0.59681E-04  0.78912E-05  0.41033E-04   8000
   ISTP= 8000     IB =    1     IROW =    1     TIME =    51.0000


   J=     1     Y=    0.2431     CL=    0.0073     CD=    0.1670     CM=    0.0141


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL     X/CU      CPL      CPU
 -0.0725  0.0000  0.0000  0.8522 -0.2085         *                         I     +
 -0.0709  0.0093  0.0107  0.8690 -0.0716         *                         I +
 -0.0692  0.0198  0.0227  0.6353 -0.3704                *                  I          +
 -0.0672  0.0317  0.0363  0.6107 -0.2992                 *                 I        +
 -0.0649  0.0450  0.0516  0.3616 -0.6869                        *          I                       +
 -0.0624  0.0606  0.0682  0.3736 -0.4807                        *          I             +
 -0.0595  0.0781  0.0868  0.3016 -0.4620                          *        I             +
 -0.0563  0.0980  0.1079  0.2856 -0.3488                          *        I         +
 -0.0527  0.1203  0.1315  0.2516 -0.2686                           *       I       +
 -0.0487  0.1455  0.1581  0.2299 -0.1825                            *      I    +
 -0.0441  0.1739  0.1881  0.1996 -0.1226                             *     I   +
 -0.0389  0.2059  0.2218  0.1457 -0.1149                               *   I  +
 -0.0331  0.2419  0.2597  0.0601 -0.1646                                 * I    +
 -0.0260  0.2864  0.3065 -0.0414 -0.2173                                   I*     +
 -0.0188  0.3310  0.3533 -0.1341 -0.2443                                   I   *  +
 -0.0116  0.3756  0.3999 -0.2014 -0.2587                                   I     * +
 -0.0045  0.4203  0.4463 -0.2383 -0.2694                                   I      *+
  0.0027  0.4654  0.4923 -0.2258 -0.2458                                   I      *
  0.0098  0.5113  0.5376 -0.1730 -0.1875                                   I    *+
  0.0170  0.5578  0.5823 -0.1355 -0.1479                                   I   *
  0.0241  0.6044  0.6267 -0.1374 -0.1480                                   I   *
  0.0313  0.6511  0.6709 -0.1332 -0.1451                                   I   *
  0.0384  0.6978  0.7149 -0.1147 -0.1277                                   I  *+
  0.0455  0.7443  0.7591 -0.0867 -0.1013                                   I  *
  0.0513  0.7819  0.7948 -0.0615 -0.0715                                   I *
  0.0564  0.8154  0.8263 -0.0388 -0.0490                                   I*
  0.0609  0.8452  0.8543 -0.0214 -0.0329                                   I*
  0.0649  0.8716  0.8791 -0.0049 -0.0155                                   *
  0.0685  0.8950  0.9012  0.0130  0.0049                                   *
  0.0717  0.9158  0.9208  0.0346  0.0276                                  *I
  0.0745  0.9343  0.9382  0.0596  0.0582                                 * I
  0.0770  0.9508  0.9536  0.0919  0.0901                                *  I
  0.0792  0.9653  0.9674  0.1219  0.1300                               *   I
  0.0812  0.9783  0.9795  0.1587  0.1694                              *    I
  0.0829  0.9898  0.9904  0.1903  0.2181                            +*     I
  0.0845  1.0000  1.0000  0.2315  0.2625                           +*      I
```

```
     J=     2     Y=    0.2642     CL=   0.0017     CD=   0.1671     CM=   0.0101

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL      CPU
 -0.0784  0.0000  0.0000  0.8454 -0.2070          *                   I     +
 -0.0768  0.0093  0.0107  0.8620 -0.0711         *                    I +
 -0.0750  0.0198  0.0227  0.6303 -0.3676                *             I          +
......
```

*** Several lines deleted ***

```
......
  0.0781  0.9784  0.9793  0.1573  0.1679                          *  I
  0.0799  0.9898  0.9903  0.1886  0.2162                         *   I
  0.0814  1.0000  1.0000  0.2295  0.2602                       +*    I

......
```

*** Several sets of pressure coefficient output deleted ***

```
......

     J=    20     Y=    1.0000     CL=   0.3100     CD=   0.4032     CM=   0.0048

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL      CPU
  0.0765  0.0000  0.0000  0.3912 -1.1560                         *   I          +
  0.0771  0.0088  0.0103  0.3909 -1.0886                         *   I         +
  0.0777  0.0187  0.0218  0.3750 -1.0518                         *   I         +
......
```

*** Several lines deleted ***

```
......
  0.1350  0.9769  0.9785  0.1010 -0.0005                        * I+
  0.1357  0.9892  0.9899  0.1052  0.0082                        * +
  0.1363  1.0000  1.0000  0.1109  0.0159                        * +
     ISTP= 8000     IB =    2     IROW =    1     TIME =    51.0000

     J=     1     Y=    0.2431     CL=   0.0051     CD=   0.1425     CM=   0.0149

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL      CPU
 -0.0725  0.0000  0.0000  0.8482 -0.2096          *                   I     +
 -0.0709  0.0093  0.0107  0.8636 -0.0715         *                    I +
 -0.0692  0.0198  0.0227  0.6297 -0.3720                *             I          +
......
```

*** Several lines deleted ***

```
......
  0.0812  0.9783  0.9795  0.1528  0.1766                          *  I
  0.0829  0.9898  0.9904  0.1858  0.2244                        +*   I
  0.0845  1.0000  1.0000  0.2275  0.2684                       +*    I

......
```

*** Several sets of pressure coefficient output deleted ***

```
......

     J=    20     Y=    1.0000     CL=    0.2602     CD=    0.3402     CM=    0.0055


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000  0.3321 -0.8697                                 *   I         +
  0.0771  0.0088  0.0103  0.3229 -0.8131                                 *   I        +
  0.0777  0.0187  0.0218  0.3168 -0.7989                                 *   I        +
......
```

*** Several lines deleted ***

```
......
  0.1350  0.9769  0.9785  0.1105  0.0306                                  * +
  0.1357  0.9892  0.9899  0.1124  0.0426                                  *+I
  0.1363  1.0000  1.0000  0.1198  0.0490                                  *+I

......
```

*** Pressure coefficient output for blades 3,4,5,6 and 7 deleted ***

```
......

     ISTP= 8000     IB =    8     IROW =    1     TIME =    51.0000


     J=     1     Y=    0.2431     CL=    0.0051     CD=    0.1407     CM=    0.0138


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.8471 -0.1939        *                       I    +
 -0.0709  0.0093  0.0107  0.8625 -0.0585       *                        I +
 -0.0692  0.0198  0.0227  0.6279 -0.3568             *                  I         +
......
```

*** Several lines deleted ***

```
......
  0.0812  0.9783  0.9795  0.1588  0.1792                                  *    I
  0.0829  0.9898  0.9904  0.1914  0.2273                                +*     I
  0.0845  1.0000  1.0000  0.2326  0.2717                               +*      I

......
```

*** Several sets of pressure coefficient output deleted ***

```
......

     J=    20     Y=    1.0000     CL=    0.2786     CD=    0.3648     CM=    0.0061


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000  0.3518 -0.9005              *        I                    +
  0.0771  0.0088  0.0103  0.3445 -0.8436              *        I                  +
  0.0777  0.0187  0.0218  0.3373 -0.8306              *        I                 +
......
```

*** Several lines deleted ***

```
......
```

```
  0.1350  0.9769  0.9785  0.1209  0.0342                       * +I
  0.1357  0.9892  0.9899  0.1227  0.0460                       * +I
  0.1363  1.0000  1.0000  0.1291  0.0530                       * +I
   FOR THE SINGLE ROTATION PROPFAN :
     ADVANCE RATIO =          3.55000000
     POWER COEFFICIENT =      1.92997793
     THRUST COEFFICIENT =    0.12837285
     EFFICIENCY =             0.23612892
inlet mach no.=   0.477 u=  0.0001 v=  0.0000 w= -0.4770 ql=  1.0159 p=  0.7303 r=  0.01000 j=  1
exit mach no.=   0.475 u=  0.0320 v= -0.0336 w= -0.4723 ql=  1.0274 p=  0.7143 r=  0.15465 j=  1
inlet mach no.=   0.484 u=  0.0014 v=  0.0018 w= -0.4842 ql=  1.0159 p=  0.7303 r=  0.02469 j=  2
exit mach no.=   0.493 u=  0.0299 v= -0.0364 w= -0.4903 ql=  1.0274 p=  0.7143 r=  0.16501 j=  2
......
```

*** Several lines deleted ***

```
......
inlet mach no.=   0.478 u= -0.0041 v= -0.0039 w= -0.4780 ql=  1.0231 p=  0.7371 r=  0.49923 j= 20
exit mach no.=   0.582 u=  0.0370 v= -0.0841 w= -0.5751 ql=  0.9527 p=  0.7143 r=  0.49994 j= 20
inlet mach no.=   0.466 u=  0.0069 v=  0.0104 w= -0.4659 ql=  1.0231 p=  0.7371 r=  0.50200 j= 21
exit mach no.=   0.587 u=  0.0597 v= -0.0581 w= -0.5810 ql=  0.9527 p=  0.7143 r=  0.50200 j= 21
  Relative Mach No. at Tip =0.8592039059919863
  Relative Mach No. at Tip (Mid Plane)=0.6531971713379576
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  The Following Quantities are at I =5 Z=1.102164637904551
  Mass Flow Rate =-0.2362110693740211 (lb/s) Corrected =-0.2383192278077946 (lb/s @ 518.7R & 14.7psi)
  The Following Quantities are at I =50 Z=2.053126919559777E-2
  Mass Flow Rate =-0.2182021680198378 (lb/s) Corrected =-0.2201495989425197 (lb/s @ 518.7R & 14.7psi)
  The Following Quantities are at I =95 Z=-0.8030763509607972
  Mass Flow Rate =-0.23538939944868 (lb/s) Corrected =-0.2374902245665869 (lb/s @ 518.7R & 14.7psi)
       TIME/ITERATION =5.054890234375279
```

UNIT 57 (output file; contains blade motion)

```
    1    1     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    1     0.30000E-02   -0.30000E-04   -0.29998E-04   -0.29995E-04
    1    2     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    2     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    3     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    3     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    4     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    4     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    5     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    5     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    6     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    6     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    7     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    7     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    8     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    1    8     0.30000E-02    0.00000E+00    0.00000E+00    0.00000E+00
    2    1     0.60000E-02   -0.59998E-04   -0.59994E-04   -0.59981E-04
    2    2     0.60000E-02   -0.18703E-09    0.87707E-10    0.11198E-09
    2    3     0.60000E-02   -0.18633E-09    0.88173E-10    0.11238E-09
    2    4     0.60000E-02   -0.18629E-09    0.88153E-10    0.11231E-09
    2    5     0.60000E-02   -0.18630E-09    0.88155E-10    0.11231E-09
    2    6     0.60000E-02   -0.18640E-09    0.88187E-10    0.11250E-09
```

```
    2     7     0.60000E-02   -0.18645E-09    0.88196E-10    0.11256E-09
    2     8     0.60000E-02   -0.18954E-09    0.84927E-10    0.10935E-09
......
```

*** 31960 lines of output deleted ***

```
......
 7999     1     0.23997E+02   -0.17842E-01   -0.24180E-02   -0.11148E-02
 7999     2     0.23997E+02    0.23842E-01    0.76851E-03    0.12358E-02
 7999     3     0.23997E+02   -0.17483E-01    0.75404E-03   -0.63258E-03
 7999     4     0.23997E+02    0.63099E-02   -0.16356E-02    0.47851E-04
 7999     5     0.23997E+02    0.66070E-02    0.87060E-03    0.44963E-03
 7999     6     0.23997E+02   -0.13214E-01    0.87076E-03   -0.43357E-03
 7999     7     0.23997E+02    0.11088E-01   -0.26762E-02    0.79512E-04
 7999     8     0.23997E+02    0.30939E-02    0.30853E-02    0.63468E-03
 8000     1     0.24000E+02   -0.17607E-01   -0.24526E-02   -0.11112E-02
 8000     2     0.24000E+02    0.23703E-01    0.80490E-03    0.12362E-02
 8000     3     0.24000E+02   -0.17481E-01    0.73137E-03   -0.63683E-03
 8000     4     0.24000E+02    0.64080E-02   -0.16337E-02    0.53163E-04
 8000     5     0.24000E+02    0.65176E-02    0.88483E-03    0.44746E-03
 8000     6     0.24000E+02   -0.13243E-01    0.85234E-03   -0.43733E-03
 8000     7     0.24000E+02    0.11262E-01   -0.26692E-02    0.88096E-04
 8000     8     0.24000E+02    0.28443E-02    0.31009E-02    0.62577E-03
```

UNIT 98 (output file; contains performance characteristics)

```
ITERATION     CP          CT          EFF
 1,  1.92620107182389,  0.1275021397257223,  0.2349871997515409
 2,  1.926114049173954,  0.1274739896345745,  0.2349459334439805
 3,  1.926289471125479,  0.1275160234299531,  0.2350020025348751
 4,  1.926291492274117,  0.1275060683057845,  0.2349834094689145
 5,  1.926474934642208,  0.1275499018171331,  0.2350418078680683
 6,  1.926484118524925,  0.127541577318123,  0.2350253475362241
 7,  1.926673880349846,  0.127586869910183,  0.235085653467678
 8,  1.926688548735548,  0.1275798366527328,  0.2350709046433259
 9,  1.926883023202492,  0.1276262620111526,  0.2351327115781965
 10,  1.926901589167571,  0.127620196140664,  0.2351192706707348
......
```

*** 7980 output lines deleted ***

```
......
 7991,  1.930040822740146,  0.1283892422466169,  0.236151383227428
 7992,  1.929955963471393,  0.1283639661860363,  0.2361152733976279
 7993,  1.930046459725382,  0.1283914194507298,  0.2361546981179634
 7994,  1.9299615656981,  0.1283661552163595,  0.2361186145451768
 7995,  1.930052027836766,  0.1283936205662055,  0.2361580653972801
 7996,  1.929967096753209,  0.1283683669098066,  0.2361220060675935
 7997,  1.93005752221741,  0.1283958430210248,  0.2361614809288026
 7998,  1.929972551902672,  0.1283705986969279,  0.2361254438177509
 7999,  1.930062938632268,  0.1283980843338659,  0.2361649406667707
 8000,  1.929977927285918,  0.1283728481678734,  0.2361289238353228
```

6.3 Frequency Domain Aeroelastic Analysis of an Isolated Fan Row

Description:

A test case for frequency domain aeroelastic analysis for all the possible interblade phase angles is provided here. The fan analyzed has eight blades and first three normal modes are included in the

analysis. It is identical to the case analyzed using time domain method, for which the sample case was presented in section 6.2. Again, as mentioned in section 6.2, a steady aerodynamic solution is first generated using the sample case provided in 6.1 for the desired flow conditions. The aeroelastic analysis is then carried out by restarting the solution from the steady aerodynamic solution. In order to carry out the aeroelastic analysis, the structural grid (UNIT 3) and structural mode shapes (UNIT 4) are needed. The input file for this analysis is very similar to the steady aerodynamic analysis with changes in the lines shown below in the input file **ducte3d.inp**. The input variables RESTART and AEROELASTIC are set to TRUE, IFLTR is set to a positive integer, NSTDY to 2 and NBLOKS to 8. The input variable VIBFRE is the non-dimensional time for the duration of the pulse and JMODE is the mode number in which the blade is oscillated. The variables that need to be changed are indicated in **bold** print. All other input parameters remain the same as used in the steady aerodynamic analysis. The example given here was restarted from the steady solution presented in section 6.1 and was obtained by running the code for 9000 time steps with dt=0.003.

For starting the aeroelastic solution, the file generated in the steady analysis run, UNIT 31, is linked to UNIT 11. For an aeroelastic restart, i.e. restarting the solution from a previous aeroelastic solution, the only change required is to link the files generated on UNITs 30+n by the previous aeroelastic analysis to UNITs 10+n of the current analysis. The analysis is repeated with the variable JMODE varying over the number of normal modes included in the analysis.

In addition to UNIT 98, other output files are generated in the analysis. The output file on UNIT 57 contains the time history of the prescribed normal mode displacement for the reference blade. Since three modes are included in the analysis, the analysis is carried out for a total of three times, once each for vibration of the reference blade in each of the three modes, *i. e.* once each for JMODE = 1, 2, & 3. Files on UNITs 93 through 95 contain the generalized forces for the three different modes due to oscillation in the given mode (JMODE). In all, nine files containing generalized forces, three files each corresponding to the three modes, are generated. These nine files along with the output file on UNIT 57 are Fourier analyzed using a post processor to provide the variation of aerodynamic damping with frequency for each of the three modes and for all possible interblade phase angles.

UNIT 5 (ducte3d.inp; input file)

```
SR3D Only one direction marching (from root to tip)
......
*** same as steady aerodynamic input, see section 6.1 ***
......
    FSTP     FMINF    BETA34      DIA       DX        DZ     VIBFRE
   4000.0    0.500    61.20       1.0      0.01     0.030      1.8
     ICCW    ITURB    LTHIN       IGR      ISWF
       1       0        0          0        0
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD, DUCT
 TRUE TRUEFALSE TRUEFALSEFALSE TRUE
     IFLTR     NUMCYC     NSTDY     JMODE     NBLOKS
       1         0          2         1          8
```

FNRS

••••••

*** same as steady aerodynamic input, see section 6.1 ***

••••••

UNIT 6 (ducte3d.out; output file)

```
1     SR3-Ducted Propfan, flat plate infinite duct
 *******************************************************
 *       aeroelastic stability analysis               *
 *     using normal mode structural model             *
 *       with Euler aerodynamic model in              *
 *             FREQUENCY DOMAIN                       *
 *            using Pulse Motion                      *
 *******************************************************
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.69999999999999
 +  speed of sound (in/sec)=13040.
 +  density=1.210292069705291E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=0.
 *  rotor speed(rad/sec)=0.
 *  Mach no.= 0.5
 *  advance ratio (J).= 3.549999999999997
 *  tip radius (inches)=0.5
 ----------------------------------------

 RESTART RUN FROM A PREVIOUS SOLUTION
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  CHARACTERISTICS USED TO UPDATE UPSTREAM BOUNDARY
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =    2
      IKDIS =    1
      IJ2   =    0
      IIDIS =    1
      IHPQ  =    1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
      IWHIT =    0
      INL  =    1
      IEX   =    2
      JEX   =    1
      INRES =0
      IHORD =0
      KHORD =0
      ISMTH =0
      KSMTH =0
      IVIBR =1
        WWF =100.


     IMAX=        100
     JMAX=         21
     KMAX=         16
```

```
JTIP=        20
ITEL=        71
ILE =        36
INOSE=        16
NSTEP=      4000
 DX =          0.01000000
 DZ =          0.03000000
  DT=          0.00300000
  WW=          7.00000000
ALFA=          0.00000000
AMTIP=          0.44247784
FMINF=           0.50000000
ADVANCE RATIO =   3.55000000
vibration freq. =   1.80000000
VIBRATING IN    1  MODE


 GMU=          0.00000000
**** NSTDY =2
**** JMODE =1
cosa=1. sina=0.
NUMBER OF TIME STEPS FOR ONE CYCLE = 1163
TOTAL NUMBER OF STEPS FOR 0 CYCLES =4000
TOTAL NUMBER OF STEPS  4000
reyref=-1000000. reynum=0.
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
MAX JACOB=7.999591762776047E-5 MIN JACOB=8.441722412234353E-9 AT 20
IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
MAX JACOB=1.151533808997819E-4 MIN JACOB=1.291499186729728E-8 AT 19
IJMAX=2 KJMAX=8 IJMIN=36 KJMIN=2
```

......

*** Several lines of Jacobian output deleted ***

......

```
MAX JACOB=7.990930162917559E-5 MIN JACOB=1.406906985237722E-7 AT 3
IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14
MAX JACOB=5.501060715851278E-5 MIN JACOB=1.043742011269572E-7 AT 2
IJMAX=99 KJMAX=8 IJMIN=71 KJMIN=14

 DRMAX       DUMAX       DVMAX       DWMAX       DEMAX       IB    IROW   IR   JR   KR
 0.9133E-04  0.4960E-03  0.5190E-03  0.1082E-04  0.2352E-03       1    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.4793E-03  0.4699E-03  0.1087E-04  0.2352E-03       2    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.5190E-03  0.4960E-03  0.1089E-04  0.2352E-03       3    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.4699E-03  0.4791E-03  0.1089E-04  0.2352E-03       4    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.4960E-03  0.5190E-03  0.1086E-04  0.2352E-03       5    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.4793E-03  0.4699E-03  0.1083E-04  0.2352E-03       6    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.5190E-03  0.4960E-03  0.1089E-04  0.2352E-03       7    1   87   19    5
FMINF=0.5 SMINF=0. ICBU=1 ICBD=100
imax=100 jmax=21 kmax=15 ngp=27720
 0.9133E-04  0.4699E-03  0.4791E-03  0.1086E-04  0.2352E-03       8    1   87   19    5
```

```
 READING NASTRAN DATA: GRID COORDINATES
DIAMET = 25.12798087312228
BETGRD = 60.51058046349885DBET =-0.6894195793147446
MODAL DISPLACEMENTS: MODE 1
GMASS =2.408412999999997E-5 FREQ(hz) =221.0820000000003
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 2
GMASS =2.444044E-5 FREQ(hz) =402.1286999999993
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 3
GMASS =1.445758000000001E-5 FREQ(hz) =698.2001999999993
FINISHED READING NASTRAN DATA
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
 xa=1.467114822884277 ya=12.47803789802464 za=-1.92224411965627
 xt=2.54213610884841 yt=12.30412124827461 zt=-3.425739536709216
 xn=-3.323947690990835 yn=12.25 zn=2.751504279036567
 dxn=1.006955944440207 dyn=-0.2032965999999998 dzn=0.5720452635347399
*  tip radius for structural model (inches)=12.56399043656114
NUMBER OF TIME STEPS FOR ONE REVOLUTION =  2366
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
   0.9134E-04  0.4792E-03  0.5099E-03  0.9708E-05  0.2351E-03    1   1   87   19   5
   0.9134E-04  0.4780E-03  0.4589E-03  0.9718E-05  0.2351E-03    2   1   87   19   5
   0.9134E-04  0.5099E-03  0.4792E-03  0.9718E-05  0.2351E-03    3   1   87   19   5
   0.9134E-04  0.4589E-03  0.4783E-03  0.9721E-05  0.2351E-03    4   1   87   19   5
   0.9134E-04  0.4792E-03  0.5099E-03  0.9718E-05  0.2351E-03    5   1   87   19   5
   0.9134E-04  0.4781E-03  0.4589E-03  0.9708E-05  0.2351E-03    6   1   87   19   5
   0.9134E-04  0.5099E-03  0.4792E-03  0.9717E-05  0.2351E-03    7   1   87   19   5
   0.9134E-04  0.4589E-03  0.4783E-03  0.9714E-05  0.2351E-03    8   1   87   19   5
......
```

*** Several output lines deleted ***

```
......
   0.9134E-04  0.4702E-03  0.5106E-03  0.1262E-04  0.2352E-03    1   1   87   19   5
   0.9134E-04  0.4787E-03  0.4549E-03  0.9771E-05  0.2351E-03    2   1   87   19   5
   0.9134E-04  0.5106E-03  0.4702E-03  0.9766E-05  0.2351E-03    3   1   87   19   5
   0.9134E-04  0.4549E-03  0.4789E-03  0.9768E-05  0.2351E-03    4   1   87   19   5
   0.9134E-04  0.4702E-03  0.5106E-03  0.9770E-05  0.2351E-03    5   1   87   19   5
   0.9134E-04  0.4787E-03  0.4549E-03  0.9761E-05  0.2351E-03    6   1   87   19   5
   0.9134E-04  0.5106E-03  0.4702E-03  0.9765E-05  0.2351E-03    7   1   87   19   5
   0.9140E-04  0.4549E-03  0.4789E-03  0.1345E-04  0.2353E-03    8   1   87   19   5
 AVERAGE RESIDUES --  0.92106E-05  0.93287E-04  0.60442E-04  0.68117E-06  0.23261E-04   50
 AVERAGE RESIDUES --  0.93402E-05  0.76889E-04  0.72812E-04  0.55098E-06  0.23580E-04   50
 AVERAGE RESIDUES --  0.93426E-05  0.60381E-04  0.93388E-04  0.55016E-06  0.23586E-04   50
 AVERAGE RESIDUES --  0.93426E-05  0.72811E-04  0.76893E-04  0.55036E-06  0.23586E-04   50
 AVERAGE RESIDUES --  0.93426E-05  0.93388E-04  0.60382E-04  0.55036E-06  0.23586E-04   50
 AVERAGE RESIDUES --  0.93425E-05  0.76891E-04  0.72811E-04  0.55012E-06  0.23585E-04   50
 AVERAGE RESIDUES --  0.93415E-05  0.60377E-04  0.93389E-04  0.54986E-06  0.23583E-04   50
 AVERAGE RESIDUES --  0.94877E-05  0.72662E-04  0.76980E-04  0.64916E-06  0.23960E-04   50
```

......

*** Several output lines deleted ***

......

```
 AVERAGE RESIDUES --  0.90865E-05  0.68685E-04  0.81489E-04  0.46008E-06  0.23375E-04    3950
 AVERAGE RESIDUES --  0.91206E-05  0.91766E-04  0.61917E-04  0.43612E-06  0.23399E-04    3950
 AVERAGE RESIDUES --  0.91277E-05  0.81580E-04  0.68737E-04  0.44664E-06  0.23435E-04    3950
 AVERAGE RESIDUES --  0.91675E-05  0.61861E-04  0.91710E-04  0.43119E-06  0.23516E-04    3950
 AVERAGE RESIDUES --  0.91862E-05  0.68713E-04  0.81599E-04  0.42099E-06  0.23606E-04    3950
 AVERAGE RESIDUES --  0.91775E-05  0.91726E-04  0.61886E-04  0.41797E-06  0.23534E-04    3950
 AVERAGE RESIDUES --  0.91148E-05  0.81472E-04  0.68655E-04  0.43720E-06  0.23459E-04    3950
 AVERAGE RESIDUES --  0.91503E-05  0.61948E-04  0.91773E-04  0.43824E-06  0.23434E-04    3950
   0.9147E-04  0.4529E-03  0.4977E-03  0.1325E-04  0.2355E-03        1    1   87   19    5
   0.9149E-04  0.4717E-03  0.5128E-03  0.1380E-04  0.2355E-03        2    1   87   19    5
   0.9149E-04  0.4984E-03  0.4528E-03  0.1429E-04  0.2355E-03        3    1   87   19    5
   0.9137E-04  0.5126E-03  0.4717E-03  0.1151E-04  0.2352E-03        4    1   87   19    5
   0.9127E-04  0.4527E-03  0.4976E-03  0.1031E-04  0.2349E-03        5    1   87   19    5
   0.9131E-04  0.4716E-03  0.5126E-03  0.1040E-04  0.2350E-03        6    1   87   19    5
   0.9132E-04  0.4998E-03  0.4528E-03  0.1039E-04  0.2351E-03        7    1   87   19    5
   0.9142E-04  0.5127E-03  0.4717E-03  0.1124E-04  0.2354E-03        8    1   87   19    5
   0.9128E-04  0.4575E-03  0.4896E-03  0.1347E-04  0.2350E-03        1    1   87   19    5
   0.9129E-04  0.4651E-03  0.4981E-03  0.1360E-04  0.2350E-03        2    1   87   19    5
   0.9130E-04  0.4896E-03  0.4574E-03  0.1501E-04  0.2351E-03        3    1   87   19    5
   0.9143E-04  0.4979E-03  0.4652E-03  0.1160E-04  0.2354E-03        4    1   87   19    5
   0.9149E-04  0.4573E-03  0.4896E-03  0.1032E-04  0.2355E-03        5    1   87   19    5
   0.9145E-04  0.4651E-03  0.4979E-03  0.1017E-04  0.2354E-03        6    1   87   19    5
   0.9141E-04  0.4896E-03  0.4574E-03  0.1021E-04  0.2353E-03        7    1   87   19    5
   0.9131E-04  0.4979E-03  0.4651E-03  0.1071E-04  0.2351E-03        8    1   87   19    5
   0.9128E-04  0.4692E-03  0.4940E-03  0.1358E-04  0.2350E-03        1    1   87   19    5
 AVERAGE RESIDUES --  0.90529E-05  0.65046E-04  0.85562E-04  0.45816E-06  0.23356E-04    4000
   0.9129E-04  0.4667E-03  0.4891E-03  0.1402E-04  0.2350E-03        2    1   87   19    5
 AVERAGE RESIDUES --  0.91060E-05  0.88919E-04  0.63850E-04  0.43627E-06  0.23387E-04    4000
   0.9131E-04  0.4940E-03  0.4690E-03  0.1563E-04  0.2351E-03        3    1   87   19    5
 AVERAGE RESIDUES --  0.91013E-05  0.85643E-04  0.65093E-04  0.44553E-06  0.23426E-04    4000
   0.9144E-04  0.4889E-03  0.4667E-03  0.1232E-04  0.2355E-03        4    1   87   19    5
 AVERAGE RESIDUES --  0.91517E-05  0.63778E-04  0.88852E-04  0.42695E-06  0.23522E-04    4000
   0.9148E-04  0.4689E-03  0.4940E-03  0.1032E-04  0.2355E-03        5    1   87   19    5
 AVERAGE RESIDUES --  0.91574E-05  0.65089E-04  0.85685E-04  0.41750E-06  0.23587E-04    4000
   0.9145E-04  0.4666E-03  0.4890E-03  0.1018E-04  0.2354E-03        6    1   87   19    5
 AVERAGE RESIDUES --  0.91433E-05  0.88858E-04  0.63779E-04  0.41834E-06  0.23495E-04    4000
   0.9140E-04  0.4940E-03  0.4690E-03  0.1022E-04  0.2352E-03        7    1   87   19    5
 AVERAGE RESIDUES --  0.90906E-05  0.85574E-04  0.65034E-04  0.43345E-06  0.23442E-04    4000
   0.9131E-04  0.4889E-03  0.4666E-03  0.1073E-04  0.2350E-03        8    1   87   19    5
 AVERAGE RESIDUES --  0.91257E-05  0.63867E-04  0.88915E-04  0.43380E-06  0.23413E-04    4000
    ISTP= 4000     IB =    1     IROW =    1     TIME =   39.0000


    J=     1     Y=    0.2431     CL=   0.0061     CD=   0.1525     CM=   0.0143


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL   X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.8489 -0.2046          *                        I     +
 -0.0709  0.0093  0.0107  0.8647 -0.0679         *                         I +
 -0.0692  0.0198  0.0227  0.6310 -0.3670                *                  I          +
 -0.0672  0.0317  0.0363  0.6057 -0.2933                 *                 I        +
 -0.0649  0.0450  0.0516  0.3560 -0.6828                        *          I                   +
 -0.0624  0.0606  0.0682  0.3675 -0.4748                        *          I             +
 -0.0595  0.0781  0.0868  0.2950 -0.4555                          *        I             +
 -0.0563  0.0980  0.1079  0.2788 -0.3433                           *       I         +
 -0.0527  0.1203  0.1315  0.2444 -0.2627                            *      I       +
 -0.0487  0.1455  0.1581  0.2223 -0.1763                            *      I    +
 -0.0441  0.1739  0.1881  0.1916 -0.1163                             *     I   +
```

```
 -0.0389  0.2059  0.2218  0.1374 -0.1085                               *   I  +
 -0.0331  0.2419  0.2597  0.0514 -0.1578                                 * I    +
 -0.0260  0.2864  0.3065 -0.0506 -0.2101                                   I *   +
 -0.0188  0.3310  0.3533 -0.1438 -0.2365                                   I   *  +
 -0.0116  0.3756  0.3999 -0.2115 -0.2505                                   I     * +
 -0.0045  0.4203  0.4463 -0.2486 -0.2607                                   I      *+
  0.0027  0.4654  0.4923 -0.2361 -0.2366                                   I      *
  0.0098  0.5113  0.5376 -0.1831 -0.1780                                   I    +*
  0.0170  0.5578  0.5823 -0.1452 -0.1384                                   I   *
  0.0241  0.6044  0.6267 -0.1468 -0.1385                                   I   *
  0.0313  0.6511  0.6709 -0.1421 -0.1358                                   I   *
  0.0384  0.6978  0.7149 -0.1231 -0.1185                                   I   *
  0.0455  0.7443  0.7591 -0.0944 -0.0925                                   I  *
  0.0513  0.7819  0.7948 -0.0683 -0.0634                                   I *
  0.0564  0.8154  0.8263 -0.0450 -0.0413                                   I*
  0.0609  0.8452  0.8543 -0.0270 -0.0257                                   I*
  0.0649  0.8716  0.8791 -0.0098 -0.0088                                   *
  0.0685  0.8950  0.9012  0.0089  0.0108                                   *
  0.0717  0.9158  0.9208  0.0314  0.0329                                  *I
  0.0745  0.9343  0.9382  0.0569  0.0632                                 * I
  0.0770  0.9508  0.9536  0.0895  0.0948                                *  I
  0.0792  0.9653  0.9674  0.1197  0.1347                               *   I
  0.0812  0.9783  0.9795  0.1567  0.1739                              *    I
  0.0829  0.9898  0.9904  0.1889  0.2221                            +*     I
  0.0845  1.0000  1.0000  0.2303  0.2663                           +*      I


     J=      2     Y=    0.2642     CL=    0.0003     CD=    0.1527     CM=    0.0103


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
 -0.0784  0.0000  0.0000  0.8421 -0.2029          *                        I     +
 -0.0768  0.0093  0.0107  0.8578 -0.0673         *                         I +
 -0.0750  0.0198  0.0227  0.6259 -0.3640                *                  I          +
......
```

*** Several lines deleted ***

```
......
  0.0781  0.9784  0.9793  0.1554  0.1723                              *    I
  0.0799  0.9898  0.9903  0.1873  0.2202                            +*     I
  0.0814  1.0000  1.0000  0.2283  0.2640                           +*      I
......
```

*** Several sets of pressure coefficient output deleted ***

```
......
J=    20     Y=    1.0000     CL=    0.2872     CD=    0.3748     CM=    0.0054


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000  0.3652 -1.0048           *         I                              +
  0.0771  0.0088  0.0103  0.3599 -0.9427           *         I                            +
  0.0777  0.0187  0.0218  0.3496 -0.9191           *         I                           +
......
```

*** Several lines deleted ***

```
......
  0.1350  0.9769  0.9785  0.1085  0.0170                  *  +
  0.1357  0.9892  0.9899  0.1114  0.0274                  *  +
  0.1363  1.0000  1.0000  0.1177  0.0346                  * +I
```

```
     ISTP= 4000     IB =    2     IROW =    1     TIME =   39.0000


     J=     1     Y=    0.2431     CL=   0.0061     CD=   0.1525     CM=   0.0143


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
 -0.0725  0.0000  0.0000  0.8488 -0.2046           *                        I     +
 -0.0709  0.0093  0.0107  0.8647 -0.0679          *                         I +
 -0.0692  0.0198  0.0227  0.6310 -0.3669                 *                  I          +
```

......

*** Several lines deleted ***

......

```
  0.0812  0.9783  0.9795  0.1567  0.1739                               *    I
  0.0829  0.9898  0.9904  0.1890  0.2221                             +*     I
  0.0845  1.0000  1.0000  0.2303  0.2664                            +*      I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
J=    20     Y=    1.0000     CL=   0.2871     CD=   0.3748     CM=   0.0054


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
  0.0765  0.0000  0.0000  0.3652 -1.0046            *         I                              +
  0.0771  0.0088  0.0103  0.3599 -0.9426            *         I                            +
  0.0777  0.0187  0.0218  0.3495 -0.9189            *         I                           +
```

......

*** Several lines deleted ***

......

```
  0.1350  0.9769  0.9785  0.1085  0.0170                   *  +
  0.1357  0.9892  0.9899  0.1114  0.0274                   *  +
  0.1363  1.0000  1.0000  0.1177  0.0346                   * +I
```

......

*** Pressure coefficient output for blades 3,4,5,6 and 7 deleted ***

......

```
ISTP= 4000     IB =    8     IROW =    1     TIME =   39.0000


     J=     1     Y=    0.2431     CL=   0.0061     CD=   0.1526     CM=   0.0143


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
 -0.0725  0.0000  0.0000  0.8489 -0.2048           *                        I     +
 -0.0709  0.0093  0.0107  0.8648 -0.0681          *                         I +
 -0.0692  0.0198  0.0227  0.6311 -0.3671                 *                  I          +
```

......

*** Several lines deleted ***

......

```
  0.0812  0.9783  0.9795  0.1567  0.1738                               *    I
  0.0829  0.9898  0.9904  0.1889  0.2221                             +*     I
  0.0845  1.0000  1.0000  0.2303  0.2663                            +*      I
```

......

*** Several sets of pressure coefficient output deleted ***

```
......
J=    20      Y=     1.0000      CL=    0.2872      CD=    0.3748      CM=    0.0054


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000  0.3652 -1.0049          *         I                             +
  0.0771  0.0088  0.0103  0.3599 -0.9428          *         I                           +
  0.0777  0.0187  0.0218  0.3495 -0.9192          *         I                          +
......
```

*** Several lines deleted ***

```
......
  0.1350  0.9769  0.9785  0.1084  0.0169                 *  +
  0.1357  0.9892  0.9899  0.1113  0.0274                 *  +
  0.1363  1.0000  1.0000  0.1176  0.0345                 * +I
   FOR THE SINGLE ROTATION PROPFAN :
     ADVANCE RATIO =           3.55000000
     POWER COEFFICIENT =       1.93005237
     THRUST COEFFICIENT =     0.12844400
     EFFICIENCY =              0.23625069
inlet mach no.=   0.477 u=  0.0000 v=  0.0001 w= -0.4769 ql=  1.0159 p=  0.7303 r=  0.01000 j=  1
exit mach no.=   0.471 u=  0.0197 v=  0.0424 w= -0.4691 ql=  1.0344 p=  0.7143 r=  0.15465 j=  1
inlet mach no.=   0.484 u= -0.0022 v=  0.0007 w= -0.4841 ql=  1.0159 p=  0.7303 r=  0.02469 j=  2
exit mach no.=   0.487 u=  0.0263 v=  0.0403 w= -0.4845 ql=  1.0344 p=  0.7143 r=  0.16501 j=  2
......
```

*** Several lines deleted ***

```
......
inlet mach no.=   0.478 u=  0.0051 v= -0.0023 w= -0.4781 ql=  1.0231 p=  0.7371 r=  0.49923 j= 20
exit mach no.=   0.583 u=  0.0641 v=  0.0653 w= -0.5760 ql=  0.9526 p=  0.7143 r=  0.49994 j= 20
inlet mach no.=   0.466 u= -0.0122 v=  0.0026 w= -0.4661 ql=  1.0231 p=  0.7371 r=  0.50200 j= 21
exit mach no.=   0.589 u=  0.0321 v=  0.0769 w= -0.5827 ql=  0.9526 p=  0.7143 r=  0.50200 j= 21
  Relative Mach No. at Tip =0.8810149119292667
  Relative Mach No. at Tip (Mid Plane)=0.6552965378752234
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  rho=1.210292069705291E-7 rtip=0.5 a0=13040. t0=528. p0=14.69999999999999
  The Following Quantities are at I =5 Z=1.102164637904551
  Mass  Flow  Rate  =-0.2362104564496086  (lb/s)  Corrected  =-0.2383186094130973  (lb/s  @  518.7R  &
14.7psi)
  The Following Quantities are at I =50 Z=2.053126919559777E-2
  Mass  Flow  Rate  =-0.2182055156343727  (lb/s)  Corrected  =-0.2201529764341545  (lb/s  @  518.7R  &
14.7psi)
  The Following Quantities are at I =95 Z=-0.8030763509607972
  Mass  Flow  Rate  =-0.2353501830606399  (lb/s)  Corrected  =-0.2374506581764937  (lb/s  @  518.7R  &
14.7psi)
       TIME/ITERATION =4.918026410602522
```

UNIT 57 (output file; contains blade motion)

```
    1   1    0.30000E-02    0.30153E-06    0.30153E-06    0.30153E-06
    2   1    0.60000E-02    0.12041E-05    0.12041E-05    0.12041E-05
    3   1    0.90000E-02    0.27047E-05    0.27047E-05    0.27047E-05
    4   1    0.12000E-01    0.48002E-05    0.48002E-05    0.48002E-05
    5   1    0.15000E-01    0.74876E-05    0.74876E-05    0.74876E-05
    6   1    0.18000E-01    0.10764E-04    0.10764E-04    0.10764E-04
    7   1    0.21000E-01    0.14626E-04    0.14626E-04    0.14626E-04
    8   1    0.24000E-01    0.19071E-04    0.19071E-04    0.19071E-04
    9   1    0.27000E-01    0.24095E-04    0.24095E-04    0.24095E-04
   10   1    0.30000E-01    0.29696E-04    0.29696E-04    0.29696E-04
```

.....

*** 3980 lines of output deleted ***

.....

```
 3991   1    0.11973E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3992   1    0.11976E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3993   1    0.11979E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3994   1    0.11982E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3995   1    0.11985E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3996   1    0.11988E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3997   1    0.11991E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3998   1    0.11994E+02    0.00000E+00    0.00000E+00    0.00000E+00
 3999   1    0.11997E+02    0.00000E+00    0.00000E+00    0.00000E+00
 4000   1    0.12000E+02    0.00000E+00    0.00000E+00    0.00000E+00
```

UNIT 93 (output file; contains generalized force for first mode)

```
 -1,  1,  0.,  6.747695897747867E-4,  0.
 2*1,  2*6.747695897747867E-4,  0.
 -1,  2,  -4.704826972654562E-5,  6.747695884667497E-4,  0.
 1,  2,  2*6.747695884667497E-4,  0.
 -1,  3,  -4.70482661490705E-5,  6.747695720200341E-4,  0.
 1,  3,  2*6.747695720200341E-4,  0.
 -1,  4,  -4.704824711026373E-5,  6.747695740221063E-4,  0.
 1,  4,  2*6.747695740221063E-4,  0.
 -1,  5,  -4.704824972809134E-5,  6.747695726110822E-4,  0.
 1,  5,  2*6.747695726110822E-4,  0.
 -1,  6,  -4.704824847790735E-5,  6.747695875888651E-4,  0.
 1,  6,  2*6.747695875888651E-4,  0.
 -1,  7,  -4.704826462793875E-5,  6.747695841430138E-4,  0.
 1,  7,  2*6.747695841430138E-4,  0.
 -1,  8,  -4.704825686802126E-5,  6.747695667193472E-4,  0.
 1,  8,  2*6.747695667193472E-4,  0.
 2,  1,  6.747282514998412E-4,  6.747695897747867E-4,  -4.133827494548492E-8
 2*2,  6.747282304928117E-4,  6.747695884667497E-4,  -4.135797393792217E-8
 2,  3,  6.747282364286122E-4,  6.747695720200341E-4,  -4.133559142194265E-8
 2,  4,  6.747282471448283E-4,  6.747695740221063E-4,  -4.132687727795292E-8
 2,  5,  6.7472824505466E-4,  6.747695726110822E-4,  -4.132755642219376E-8
 2,  6,  6.747282377282011E-4,  6.747695875888651E-4,  -4.13498606639806E-8
 2,  7,  6.747282223794198E-4,  6.747695841430138E-4,  -4.136176359401111E-8
 2,  8,  6.747282384831979E-4,  6.747695667193472E-4,  -4.13282361493017E-8
```

.....

*** 31960 lines of output deleted ***

.....

```
 3999,  1,  6.760029673910997E-4,  6.747695897747867E-4,  1.233377616313008E-6
 3999,  2,  6.759126944620996E-4,  6.747695884667497E-4,  1.143105995349974E-6
 3999,  3,  6.758612167654248E-4,  6.747695720200341E-4,  1.091644745390696E-6
 3999,  4,  6.757822192762184E-4,  6.747695740221063E-4,  1.012645254112182E-6
 3999,  5,  6.758859973166678E-4,  6.747695726110822E-4,  1.116424705585594E-6
```

```
3999,  6,  6.759295732602851E-4,  6.747695875888651E-4,  1.15998567142006E-6
3999,  7,  6.760323035187483E-4,  6.747695841430138E-4,  1.262719375734466E-6
3999,  8,  6.760232588532456E-4,  6.747695667193472E-4,  1.253692133898476E-6
4000,  1,  6.75961416203033E-4,  6.747695897747867E-4,  1.191826428246362E-6
4000,  2,  6.758710554035131E-4,  6.747695884667497E-4,  1.10146693676344E-6
4000,  3,  6.758195210225699E-4,  6.747695720200341E-4,  1.049949002535771E-6
4000,  4,  6.757408008077683E-4,  6.747695740221063E-4,  9.712267856620826E-7
4000,  5,  6.758449075186419E-4,  6.747695726110822E-4,  1.075334907559705E-6
4000,  6,  6.758883097063746E-4,  6.747695875888651E-4,  1.11872211750949E-6
4000,  7,  6.759910521359144E-4,  6.747695841430138E-4,  1.221467992900543E-6
4000,  8,  6.759816715907855E-4,  6.747695667193472E-4,  1.212104871438357E-6
```

UNIT 94 (output file; contains generalized force for second mode)

```
-1,  1,  0.,  -1.96979467734535E-4,  0.
2*1,  2*-1.96979467734535E-4,  0.
-1,  2,  -4.704826972654562E-5,  -1.969794624252603E-4,  0.
1,  2,  2*-1.969794624252603E-4,  0.
-1,  3,  -4.70482661490705E-5,  -1.969794605043533E-4,  0.
1,  3,  2*-1.969794605043533E-4,  0.
-1,  4,  -4.704824711026373E-5,  -1.969794630599045E-4,  0.
1,  4,  2*-1.969794630599045E-4,  0.
-1,  5,  -4.704824972809134E-5,  -1.969794625347551E-4,  0.
1,  5,  2*-1.969794625347551E-4,  0.
-1,  6,  -4.704824847790735E-5,  -1.969794630058948E-4,  0.
1,  6,  2*-1.969794630058948E-4,  0.
-1,  7,  -4.704826462793875E-5,  -1.969794566549689E-4,  0.
1,  7,  2*-1.969794566549689E-4,  0.
-1,  8,  -4.704825686802126E-5,  -1.969794587753197E-4,  0.
1,  8,  2*-1.969794587753197E-4,  0.
2,  1,  -1.969596152188923E-4,  -1.96979467734535E-4,  1.985251564268902E-8
2*2,  -1.969596054476876E-4,  -1.969794624252603E-4,  1.985697757264648E-8
2,  3,  -1.969596104058821E-4,  -1.969794605043533E-4,  1.985009847119134E-8
2,  4,  -1.969596172652424E-4,  -1.969794630599045E-4,  1.984579466214608E-8
2,  5,  -1.969596164254636E-4,  -1.969794625347551E-4,  1.984610929154501E-8
2,  6,  -1.969596095876199E-4,  -1.969794630058948E-4,  1.985341827482473E-8
2,  7,  -1.969596013466322E-4,  -1.969794566549689E-4,  1.985530833671644E-8
2,  8,  -1.969596133778736E-4,  -1.969794587753197E-4,  1.984539744603192E-8
```

•••••

*** 31960 lines of output deleted ***

•••••

```
3999,  1,  -1.979258329276693E-4,  -1.96979467734535E-4,  -9.463651931343464E-7
3999,  2,  -1.978711815557726E-4,  -1.969794624252603E-4,  -8.917191305123431E-7
3999,  3,  -1.978384393089656E-4,  -1.969794605043533E-4,  -8.589788046122967E-7
3999,  4,  -1.977841728757799E-4,  -1.969794630599045E-4,  -8.047098158754303E-7
3999,  5,  -1.978426189167201E-4,  -1.969794625347551E-4,  -8.631563819649218E-7
3999,  6,  -1.978904684605108E-4,  -1.969794630058948E-4,  -9.110054546160664E-7
3999,  7,  -1.979471391059684E-4,  -1.969794566549689E-4,  -9.67682450999513E-7
3999,  8,  -1.979480014865581E-4,  -1.969794587753197E-4,  -9.685427112384251E-7
4000,  1,  -1.979065643264756E-4,  -1.96979467734535E-4,  -9.270965919405682E-7
4000,  2,  -1.978518313866511E-4,  -1.969794624252603E-4,  -8.723689613908056E-7
4000,  3,  -1.978190028960186E-4,  -1.969794605043533E-4,  -8.395423916653099E-7
4000,  4,  -1.97764918448029E-4,  -1.969794630599045E-4,  -7.854553881244535E-7
4000,  5,  -1.978237297361532E-4,  -1.969794625347551E-4,  -8.442672013980051E-7
4000,  6,  -1.978714991423668E-4,  -1.969794630058948E-4,  -8.9203613647202E-7
4000,  7,  -1.979281220624478E-4,  -1.969794566549689E-4,  -9.486654074788644E-7
4000,  8,  -1.979287759423346E-4,  -1.969794587753197E-4,  -9.493171670149624E-7
```

UNIT 95 (output file; contains generalized force for third mode)

```
 -1,  1,  0.,  -4.704826972654562E-5,  0.
 2*1,  2*-4.704826972654562E-5,  0.
 -1,  2,  -4.704826972654562E-5,  -4.70482661490705E-5,  0.
 1,  2,  2*-4.70482661490705E-5,  0.
 -1,  3,  -4.70482661490705E-5,  -4.704824711026373E-5,  0.
 1,  3,  2*-4.704824711026373E-5,  0.
 -1,  4,  -4.704824711026373E-5,  -4.704824972809134E-5,  0.
 1,  4,  2*-4.704824972809134E-5,  0.
 -1,  5,  -4.704824972809134E-5,  -4.704824847790735E-5,  0.
 1,  5,  2*-4.704824847790735E-5,  0.
 -1,  6,  -4.704824847790735E-5,  -4.704826462793875E-5,  0.
 1,  6,  2*-4.704826462793875E-5,  0.
 -1,  7,  -4.704826462793875E-5,  -4.704825686802126E-5,  0.
 1,  7,  2*-4.704825686802126E-5,  0.
 -1,  8,  -4.704825686802126E-5,  -4.704823992645961E-5,  0.
 1,  8,  2*-4.704823992645961E-5,  0.
 2,  1,  -4.703329748282324E-5,  -4.704826972654562E-5,  1.49722437223828E-8
 2*2,  -4.703327415563128E-5,  -4.70482661490705E-5,  1.499199343921869E-8
 2,  3,  -4.703327981844156E-5,  -4.704824711026373E-5,  1.49672918221648E-8
 2,  4,  -4.703329186058228E-5,  -4.704824972809134E-5,  1.495786750905538E-8
 2,  5,  -4.703328996616515E-5,  -4.704824847790735E-5,  1.495851174220311E-8
 2,  6,  -4.703328145632475E-5,  -4.704826462793875E-5,  1.498317161400392E-8
 2,  7,  -4.703326471514708E-5,  -4.704825686802126E-5,  1.499215287418392E-8
 2,  8,  -4.703328314224113E-5,  -4.704823992645961E-5,  1.495678421848008E-8
```

.....

*** 31960 lines of output deleted ***

.....

```
3999,  1,  -4.697105640595698E-5,  -4.704826972654562E-5,  7.721332058864376E-8
 3999,  2,  -4.698504657571099E-5,  -4.70482661490705E-5,  6.321957335951068E-8
 3999,  3,  -4.697916042725324E-5,  -4.704824711026373E-5,  6.908668301048963E-8
 3999,  4,  -4.698474133355999E-5,  -4.704824972809134E-5,  6.350839453135061E-8
 3999,  5,  -4.697706219721951E-5,  -4.704824847790735E-5,  7.118628068784882E-8
 3999,  6,  -4.69767019270692E-5,  -4.704826462793875E-5,  7.156270086954887E-8
 3999,  7,  -4.696679056661007E-5,  -4.704825686802126E-5,  8.146630141119513E-8
 3999,  8,  -4.698036249715063E-5,  -4.704823992645961E-5,  6.787742930897643E-8
 4000,  1,  -4.695440064373074E-5,  -4.704826972654562E-5,  9.386908281488332E-8
 4000,  2,  -4.696842389269491E-5,  -4.70482661490705E-5,  7.984225637558926E-8
 4000,  3,  -4.69624200268076E-5,  -4.704824711026373E-5,  8.582708345612234E-8
 4000,  4,  -4.696797976531659E-5,  -4.704824972809134E-5,  8.026996277474968E-8
 4000,  5,  -4.696030717885393E-5,  -4.704824847790735E-5,  8.794129905342028E-8
 4000,  6,  -4.695996671911042E-5,  -4.704826462793875E-5,  8.82979088283331E-8
 4000,  7,  -4.695012534186538E-5,  -4.704825686802126E-5,  9.813152615587711E-8
 4000,  8,  -4.696371787679719E-5,  -4.704823992645961E-5,  8.452204966241834E-8
```

UNIT 98 (output file; contains performance characteristics)

```
ITERATION    CP         CT        EFF
 1,  1.92620107182389,  0.1275021397257223,  0.2349871997515409
 2,  1.926111588730315,  0.1274754125002433,  0.2349488560391126
 3,  1.926199250335721,  0.1275015279820106,  0.2349862945161298
 4,  1.926109766011905,  0.1274747973716321,  0.2349479446367626
 5,  1.926197369160022,  0.1275008962400435,  0.2349853597035789
 6,  1.926107853554726,  0.127474156381191,  0.2349469965132291
 7,  1.926195370100935,  0.1275002332730777,  0.2349843817222492
 8,  1.926105796700782,  0.1274734789529495,  0.2349459988429032
 9,  1.926193198863771,  0.1274995285154654,  0.2349833477228014
 10,  1.926103541851482,  0.127472754618001,  0.2349449388680886
```

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*** 3980 lines of output deleted ***

.....

```
 3991,  1.930131606146716,  0.1284681031454307,  0.2362853210184728
 3992,  1.930045152200613,  0.1284420225080583,  0.2362479340878192
 3993,  1.930133423167177,  0.1284685951117135,  0.2362860034298695
 3994,  1.930046963517654,  0.1284425145041928,  0.2362486173180187
 3995,  1.930135237948512,  0.1284690894313831,  0.2362866904425571
 3996,  1.930048771818726,  0.1284430086701267,  0.2362493049070871
 3997,  1.930137049317793,  0.1284695857774061,  0.2362873815986219
 3998,  1.930050575936747,  0.128443504679205,  0.2362499963970475
 3999,  1.930138856106126,  0.128470083821691,  0.2362880764377113
 4000,  1.930052374708843,  0.1284440022038851,  0.2362506913277826
```

7. RUN STREAM ON CRAY YMP

```
#  QSUB-r tm6243
#  QSUB-lM 8.0Mw
#  QSUB-eo
#
cd /wrk/smsriv/ducte3d/tm6243
/bin/rm *
cat > ducte3d.f << EOF
C     PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
.....
***  FORTRAN program goes here  ***
.....
END
EOF
cat > ducte3d.inp << EOF
SR3D Only one direction marching (from root to tip)
.....
***  Input file goes here  ***
.....
EOF
cft77 -V -exs -a static ducte3d.f
segldr -V -o ducte3d ducte3d.o
ln ../std621/fort.31 ./fort.11
#n ../tm6242/fort.31 ./fort.11
#n ../tm6242/fort.32 ./fort.12
#n ../tm6242/fort.33 ./fort.13
#n ../tm6242/fort.34 ./fort.14
#n ../tm6242/fort.35 ./fort.15
#n ../tm6242/fort.36 ./fort.16
#n ../tm6242/fort.37 ./fort.17
#n ../tm6242/fort.38 ./fort.18
#n grid.den fort.2
ln $HOME/sr3grd.nas fort.3
ln $HOME/sr3mod.nas fort.4
rm *.l
time ducte3d < ducte3d.inp > ducte3d.out
#v fort.7 grid.dat
```

```
#v fort.9 flow.dat
rm fort.1* fort.2* fort.6* fort.8*  fort.7*
rm fort.90 fort.91 fort.92 fort.93 *.1 ducte3d
```

8. REFERENCES

1. Srivastava, R., "An Efficient Hybrid Scheme for the Solution of Rotational Flow Around Advanced Propellers", Ph.D. Thesis, Georgia Institute of Technology, 1990.

2. Srivastava, R., Sankar, L. N., Reddy, T. S. R., and Huff, D. L., Application of an Efficient Hybrid Scheme for Aeroelastic Analysis of Advanced Propellers, *Journal of Propulsion and Power*, Vol. 7, No. 5, pp. 767-775, 1991.

3. Srivastava, R., Reddy, T. S. R. and O. Mehmed, "Flutter Analysis of Propfans Using a Three Dimensional Euler Solver", AIAA Paper 94-1549, to appear in *Journal of Propulsion and Power.*

4. Srivastava, R., and Reddy, T. S. R., "Aeroelastic Analysis of Ducted Rotors", Presented at the ASME International Symposium on CFD in Turbomachinery, San Francisco, Nov. 1995.

5 Srivastava, R. and Reddy, T. S. R., "PROP3D: A Program for 3D Euler Unsteady Aerodynamic and Aeroelastic (Flutter and Forced Response) Analysis of Propellers - version 1," NASA CR-198471, April 1996.

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R. Srivastava and T.S.R. Reddy

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University of Toledo
Department of Mechanical Engineering
Toledo, Ohio 43606

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13. ABSTRACT (*Maximum 200 words*)

The program DuctE3D is used for steady or unsteady aerodynamic and aeroelastic analysis of ducted fans. This guide describes the input data required and the output files generated, in using DuctE3D. The analysis solves three dimensional unsteady, compressible Euler equations to obtain the aerodynamic forces. A normal mode structural analysis is used to obtain the aeroelastic equations, which are solved using either the time domain or the frequency domain solution method. Sample input and output files are included in this guide for steady aerodynamic analysis and aeroelastic analysis of an isolated fan row.

14. SUBJECT TERMS

Ducted fans; Aeroelastic analysis; Unsteady aerodynamics; Euler equations; Time domain

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